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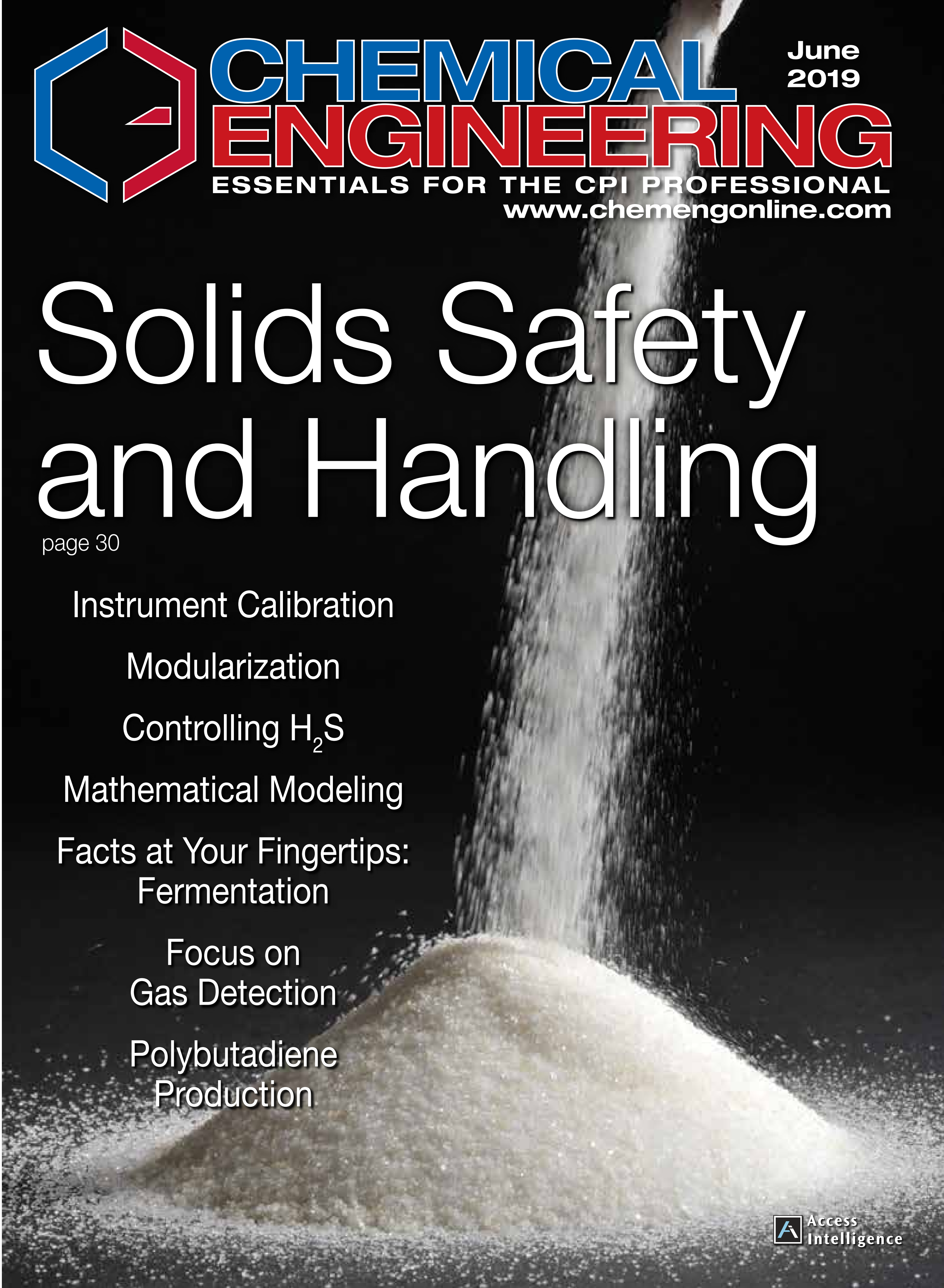

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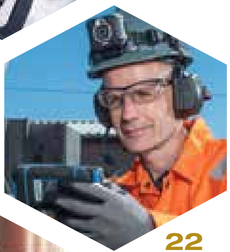

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Cover design: Rob Hudgins

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Editor's Page

2019 Kirkpatrick Award Finalists

Every two years, *Chemical Engineering* honors an innovative technology that has been commercialized with the Kirkpatrick Chemical Engineering Achievement Award. This year, we have six finalists who will have the opportunity to present their technologies at the Chem Show in New York City (October 22–24), after which the winner will be announced. Here is a brief summary of the six finalist technologies:

Braskem — Renewable EVA. A partially renewable ethylene vinyl acetate (EVA) was co-developed with Allbirds (a shoe company), where sugarcane, instead of oil was used as a raw material. A process was developed to produce a wide range of EVA and EVA-rubber products using a polymer plant that was designed to produce polyethylene. A commercial product using the new EVA was launched in 2018.

Dow Packaging and Specialty Plastics — Symbiex adhesive technology. The trademarked Symbiex technology creates multilayer packaging for foods and more by gluing together layers of different plastics to create a laminate. Developed together with Nordmeccanica, this is a new lamination concept where the two parts are not mixed prior to application, but are applied independently. The cure starts when the two coated films are brought together to form the multilayer film.

Johnson Matthey — Catacel SSR Structured Steam Reforming Catalyst. An increased demand for hydrogen has operators of steam methane reformers (SMRs) pushing their systems to maximum capacities and experiencing limitations in temperature, pressure and feed flows. The patented Catacel SSR is a catalyst-coated metal foil alternative to catalyst-impregnated pellets that can decrease pressure drop, and increase heat transfer and catalytic activity. Overall plant throughput can be increased up to 20% without capital investment for a new plant.

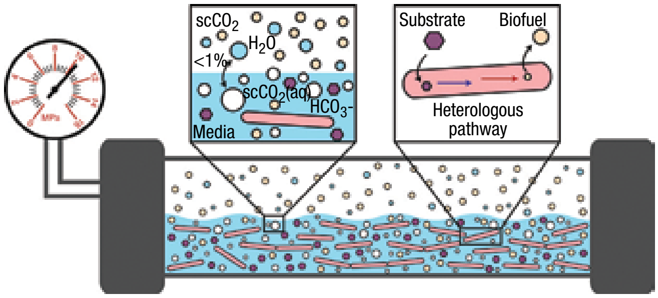
LanzaTech — Gas Fermentation Technology. This process converts carbon-rich gas streams to products using proprietary microbes that feed on gases rather than sugars, as in traditional fermentation. The source of the gases can include industrial emissions and more. LanzaTech's process takes waste carbon and produces chemicals that serve as building blocks for products such as rubber, plastics and fuels. Third-party assessments have shown greenhouse-gas-emissions reductions by over 70% compared to equivalent products from fossil carbon.

Reliance Industries — Simultaneous Production of Benzene and Gasoline from C-6 Heart Cut of FCC Gasoline. To meet the low levels of benzene allowed in gasoline, Reliance Industries and the Indian Institute of Petroleum jointly developed technology for processing the C6 heart cut of FCC (fluid catalytic cracking) gasoline based on the principles of extractive distillation without the requirement of a pre-processing step. Said to be the first of its kind, this technology produces gasoline that meets U.S. benzene limits, while also recovering high-purity benzene.

TechnipFMC — Direct Heating Unit (Flameless Combustion). This technology, jointly developed with support from Total Petrochemical and Shell Oil, is said to be a groundbreaking technology for adding heat to high-temperature processes. Unlike conventional furnace burners where fuel and air are combined at a single point, in this process, fuel is added incrementally to a high-velocity air stream via multiple injections over an extended reaction zone. As a result, the fuel reacts in a controlled manner at significantly lower temperatures than classic combustion. ■

Dorothy Lozowski, Editorial Director

Isobutanol synthesis and extraction process could reduce energy compared to alternatives



Bio-based isobutanol is attractive as a renewable blendstock for gasoline because it has higher energy density than bioethanol, and does not impose vehicle-range penalties as a fuel additive, but thus far, processes to synthesize and isolate isobutanol have required a sizable fraction of the energy embodied in the fuel. Now, a collaborative team of researchers from Worcester Polytechnic Institute (WPI; Worcester, Mass.; www.wpi.edu) and the Massachusetts Institute of Technology (MIT; Cambridge, Mass.; www.mit.edu) have devised a process for making and extracting isobutanol that could cut energy requirements by as much as a factor of five.

The biosynthesis of isobutanol is carried out by a genetically engineered microbe isolated from rock samples at a geological carbon dioxide reservoir. The MIT group, led by Kris Prather, Janelle Thompson and Jason Boock, introduced genes for isobutanol biosynthesis into the microbe (*Bacillus megaterium*), which can survive in high-pressure CO_2 environments. The ability to survive in these conditions is critical to the extraction process, which relies on supercritical CO_2.

WPI chemical engineer Mike Timko led the team that developed the extraction technique. If the supercritical-CO_2-tolerant microbe is coupled to an aqueous fermentation process, the CO_2 can be used as an extraction solvent. "Supercritical CO_2 allows us to preferentially extract isobutanol from the fermentation step with more favorable thermodynamics than conventional isobutanol processes," he says. "Then, by partially reducing the CO_2 pressure, we can separate product at low energies.

In earlier research on isobutanol processes, product yields have been low, and energy costs high, because isobutanol is toxic to microbes at only 2 wt.%, and methods to extract it, such as gas stripping, have consumed too much energy. The WPI-MIT project has calculated that it is possible to generate and extract isobutanol using its system at 2 MJ/kg, Timko says.

The team has completed proof-of-principle studies for both the biosynthesis and the extraction process, and is now working on a complete integrated process and a better understanding of microbial growth. Timko is also thinking about how to apply the extraction technique to other mid-polar compounds.

These 'imprinted' resin beads selectively recover gold from leaching processes

In early April, 6th Wave Innovations Corp. (Salt Lake City, Utah; www.6wic.com) and CyPlus GmbH (Hanau-Wolfgang, Germany; www.cyplus.com) signed a sales and marketing representative agreement for IXOS nanotech gold extraction resin for the mining industry. CyPlus will represent 6th Wave in Europe, Mexico, Turkey and Egypt. 6th Wave estimates that its molecularly imprinted polymer IXOS resin can increase gold mining profits by approximately \$100 per ounce in process savings and extra gold recovered in direct comparison and as a replacement for activated carbon, the most widely used extraction medium today.

The patented IXOS resins are "imprinted" at the molecular level to selectively attract gold and ignore the other elements from cyanide leach solutions in mining operations. Unlike conventional ion-exchange resins, the IXOS resin has a long life (more than 50 loading/unloading cycles), and high capacity (~30 g/kg) and selectivity for gold (over 95%). The unloading (elution) process is simple, straightforward and inexpensive when compared to activated carbon. The beads require no activation step for re-use. The resin is supplied ready-to-use, with a range of particle sizes available to accommodate heap leach and resin-in-leach/pulp circuits.

In laboratory and field trials conducted over the past three years, IXOS has consistently and thoroughly outperformed activated carbon and conventional ion-exchange resins, says the company. 6th Wave is operating a pilot plant at a major U.S. gold producer, and has pending projects with other mines and Canadian R&D entities.

Edited by:
Gerald Ondrey

SULFUR CONTROL

Preferential Oxidation Catalysis — a new catalytic solution from Haldor Topsoe A/S (Lyngby, Denmark: www.topsoe.com) — has been industrially proven to effectively remove undesired hydrogen sulfide in lean off-gases from viscose production at a significantly lower cost than traditional scrubbers. The new technology has been demonstrated to selectively treat different sulfur compounds in order to more efficiently remove H_2S from emissions, while retaining the valuable carbon disulfide that is reused in the production. In addition, unlike traditional scrubbing, Preferential Oxidation Catalysis does not consume costly sodium hydroxide or produce wastewater, which is troublesome to dispose of. The technology was developed and tested in the laboratory and at a small-scale industrial plant in collaboration with Birla Cellulose of the Aditya Birla Group, a leading viscose manufacturer.

The next step is building a large-scale demonstration plant in China together with Zhongtai Group in connection with a viscose plant in the Xinjiang province. The demonstration plant will be commissioned later in 2019.

NEW NH_3 PROCESS

KBR, Inc. (Houston; www.kbr.com) has successfully developed Ammonia 6000, which is based on the company's proprietary Purifier ammonia process. The Ammonia 6000 process enables expanding single-train capacity up to 6,000 metric tons per day (m.t./d) to exploit economies of scale, increase margins and reduce cost per ton of ammonia produced.

The Ammonia 6000 technology is said to provide

(Continues on p. 8)

both the lowest capital expenditures (capex) and the lowest operating expenditures (opex) per metric ton of ammonia produced in comparison to competitive offerings. The Ammonia 6000 design avoids expensive air-separation and nitrogen-wash units and utilizes an intelligent equipment layout with optimized and reduced equipment count and sizes, all of which help to leverage economies of scale and contribute to reduced capex, says KBR.

NEW MEMBRANE

Researchers from the Massachusetts Institute of Technology (MIT; www.mit.edu) have developed a new type of polymer membrane — described in a recent issue of *Advanced Materials* — that can "dramatically" improve the efficiency of natural-gas purification. Existing membranes are typically made using linear strands of polymer, says Zachary Smith, the Joseph R. Mares Career Development Professor of Chemical Engineering at MIT, who led this research effort. "These are long-chain polymers, which look like cooked spaghetti noodles at a molecular level," he says. "You can make these cooked spaghetti noodles more rigid, and in so doing you create spaces between the noodles that change the packing structure and the spacing through which molecules can permeate."

However, such materials are not sufficiently porous to allow CO_2 molecules to permeate through them at a fast-enough rate to compete with existing purification processes. Instead of using long chains of polymers, the researchers have designed membranes in which the strands look like hairbrushes, with tiny bristles on each strand. These bristles allow the polymers to separate gases much more effectively.

In laboratory experiments, the membrane was able to withstand CO_2 feed pressures of up to 51 bars without suffering plasticization, the researchers report. This compares to around 34 bars for the best-performing materials. The membrane is

(Continues on p. 9)

Electrochemical separation and compression of hydrogen

Hydrogen gas is used widely in industry, including in metal annealing, float-glass production and silicon wafer manufacturing, among others, but greater than 80% of the H_2 used for these processes is typically vented or flared as waste. A new electrochemical system allows facilities that use H_2 to recover the gas by separating and purifying it from a waste gas stream, while also compressing the gas for re-use.

Skyre Inc. (East Hartford, Conn.; www.skyre-inc.com) has developed a proprietary high-pressure electrochemical module, modeled after proton-exchange-membrane (PEM) fuel cells, to separate pure hydrogen from H_2-containing mixed-gas waste streams. Known as H_2Renew, the device works by introducing a mixed gas stream to one side of a cation-exchange membrane and applying an electric potential. When H_2 contacts a platinum-group metal catalyst in the membrane, it separates into protons (which pass through the membrane) and electrons (which complete the electrochemical circuit). As protons and electrons recombine on the other side of the cell, pure H_2 builds up and is compressed to high pressure.

"The system works like an electrochemical filter that effectively separates hydrogen from other gases and impurities, and is able to compress the gas simultaneously without any moving parts," says Skyre CEO Trent Molter. Recovering hydrogen that would have been wasted can reduce the costs of H_2 by one half compared to purchasing new cylinders or tubes of H_2, or generating the gas onsite, Molter says.

H_2Renew can produce H_2 with purities up to 99.999% and pressures up to 13,000 psi. In addition to H_2-recycling applications, H_2Renew can also be used for compression applications and for separating H_2 from helium, which has become expensive recently due to a shortage of supply.

Based on similar technology, Skyre has also developed an electrochemical cell for converting carbon dioxide into valuable fuels and chemicals.

High-strength Al alloy for 3-D printing is moving into commercial production

The first high-strength, wrought-aluminum alloy powder designed for use in additive manufacturing (3-D printing) applications is moving into commercial production. The powder was developed by HRL Laboratories (Malibu, Calif.; www.hrl.com) for use in laser powder-bed fusion 3-D printers. The company recently announced that the material has been registered by the Aluminum Association (Arlington, Va.; www.aluminum.org). The alloy material was originally described in a 2017 *Nature* paper.

High-strength wrought aluminum alloys in the 7000 and 2000 series have been used for decades because of their strength and low-cost alloying additives (Zn, Mg and Cu), explains HRL's Zak Eckel. These alloys are used widely, from aircraft components and industrial equipment to sporting goods, but they have not been successfully 3-D-printed before.

The main barrier to 3-D-printing of high-strength Al alloys from metal powder is that rapid melting and solidification of the feed material in 3-D printing gives rise to suboptimal crystal structure in the metal product. Because aluminum's coefficient of thermal expansion and other properties strain the crystal structure, cracks develop easily in the solidified aluminum.

Grain refinement in metal alloys refers to strategies to control the nucleation and growth of crystal structures with desired properties. With its Al 7A77.60L alloy, HRL has developed a targeted grain-refinement method that controls the solidification of the metal in additive manufacturing to avoid the cracking phenomenon in the end product.

"We have developed an inoculant selection method, based on matched lattices, to grow aluminum grains in a way that will generate the strength and other required properties in the product," says HRL metallurgist Hunter Martin. By functionalizing the melt pool from which solid Al can grow when solidifying in 3-D printers, we avoid large, columnar grains, Martin explains. Using zirconium, we create many points for aluminum crystal growth to occur in the desired way.

HRL is hoping to use the commercial powder to attract strategic customers looking for the performance and cost benefits of high-strength Al-alloy systems combined with the freedom of additive manufacturing. Among the initial applications of 3-D-printed Al-alloy parts is replacement parts in aging, high-value equipment for which tooling for components no longer exists.

Nitrogen fixation under ambient conditions

The transition-metal-catalyzed reduction of nitrogen is an alternative to the traditional energy-intensive Haber-Bosch process for producing ammonia. In these reaction systems, metallocenes or potassium graphite are typically used as the reducing reagent, and conjugate acids of pyridines or related compounds are used as a proton source. To develop a next-generation nitrogen-fixation system, these reagents should be low cost, readily available and environmentally friendly. Back in 2010, professor Yoshiaki Nishibayshi and colleagues at the University of Tokyo (www.t.u-tokyo.ac.jp/soe/index.html) developed a molybdenum-nitrogen complex catalyst having a PNP (phosphorus-nitrogen-phosphorus)-type pincer ligand that produces 23 molecules of NH_3 per catalyst molecule. But the catalytic activity was rather low due to the decomposition of the catalyst system during the reaction.

Now, the research teams of Nishibayshi and Kazunari Yoshizawa at Kyushu University have designed a new PNP-type pincer ligand, which combines samarium (II) diiodide (SmI_2) with alcohols or water. This new catalyst system enables the fixation of nitrogen by molybdenum complexes under ambient conditions. Up to 4,350 equivalents of ammonia can be produced (based on the molybdenum catalyst), with a turnover frequency of around 117 per minute. The amount of ammonia produced and its rate of formation are one and two orders of magnitude larger, respectively, than those achieved in artificial reaction systems reported so far, and the formation rate approaches that observed with nitrogenase enzymes. The high reactivity is achieved by a proton-coupled electron-transfer process that is enabled by weakening of the O–H bonds of alcohols and water coordinated to SmI_2. Although the current reaction is not suitable for use on an industrial scale, this work demonstrates an opportunity for further research into catalytic nitrogen fixation.

also 2,000–7,000 times more permeable than traditional membranes, according to the team.

PA CATALYST

Clariant's catalyst business unit (Munich, Germany; www.clariant.com/catalysts) recently announced the successful start-up of its new high-yield OxyMax PA 690 catalyst at Petrowidada's world-scale phthalic anhydride (PA) plant in Gresik, East Java, Indonesia. After an industry-standard ramp-up time to a high *o*-xylene load of 100 g/Nm^3, the production facility reports significantly greater yield for the first nine months of operation. The highly favorable results demonstrated at the Petrowidada plant are due to the unique design and materials employed in the new catalyst.

OxyMax PA 690 is a shell-type catalyst which is produced using Clariant's proprietary fluid-bed coating technology. In the process, the catalytically active materials titanium dioxide and vanadium pentoxide along with special promoters

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are coated in a thin shell onto ceramic rings. The thin, porous shell resolves mass- and heat-transport challenges during selective oxidation of *o*-xylene to PA. Hence, overoxidation is reduced, and unwanted byproducts, such as carbon oxides and maleic anhydride, are minimized. The shell, combined with an improved catalyst composition and optimized mass transport properties, results in excellent selectivity and up to 116 wt.% reactor outlet PA yield — a performance that is unprecedented by previous catalyst generations, says Clariant.

PRODUCT DEVELOPMENT

Lanxess AG (Cologne, Germany; www.lanxess.com) has entered into close collaboration with Citrine Informatics (Redwood City, Calif.; https://citrine.io), a company specializing in data-driven materials development. The two companies have launched a pilot project aimed at gauging the potential of artificial intelligence (AI) for plastics production. The aim is to further optimize the glass fibers that Lanxess uses for reinforcing many of its high-performance plastics and ultimately to enhance the performance of the materials.

Glass fibers that are mixed with the plastics to increase their mechanical performance are surrounded with a sizing. This helps the glass fibers to bond more strongly with the plastic matrix, ultimately ensuring the properties required of high-performance plastics.

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Large-scale recycling of mixed plastics

Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com) is ready to commercialize a new chemical-recycling technology that can handle a wide variety of mixed plastic waste, including plastic materials that cannot be handled by conventional recycling processes. "We are modifying the front end of the existing production stream that manufactures cellulosics and acetyls to accept mixed plastic waste. We will convert those materials into the same basic building blocks that are used for products like methyl acetate and acetic anhydride," says Tim Dell, vice president of corporate innovation at Eastman.

What sets this technology apart from other chemical-recycling processes is the rapid commercialization enabled by essentially "bolting on" the new technology to Eastman's existing units and targeting specific areas of Eastman's value chain. "We processed, under controlled conditions, truckload quantities of mixed plastics into the commercial operation, so we've proven it at scale. Full commercialization is expected by the end of 2019," adds Dell. Also in the works at Eastman is a new world-scale plant to recycle waste polyester materials using methanolysis. The plant, expected to begin commercial operations in the next 2–3 years, will break down polyester waste into virgin-quality dimethyl terephthalate and mono-ethylene glycol, both of which are important building blocks for Eastman's specialty plastics business.

Disinfecting water with photocatalytic nanosheets

Scientists at the Chinese Academy of Sciences (Beijing; www.cas.cn) and Yangzhou University (Jiangsu, China; www.yzu.edu.cn) have developed a technique for purifying water by using graphitic carbon nitride sheets. They claim their technique purifies water in 30 minutes, killing more than 99.9999% of bacteria. Traditional carbon-based catalysts, such as carbon nanotubes and graphene oxide, are not effective enough because they fail to produce enough reactive oxygen to overcome pathogens.

The Chinese scientists managed to overcome those problems with a unique catalytic design. They used nanosheets of graphitic carbon nitride, an ultra-thin two-dimensional material with the right properties to absorb light and generate reactive oxygen. This material generates sufficient hydrogen peroxide to effectively kill bacteria. Unlike metal-based photocatalytic disinfectants, the scientists' technique achieves a high level of water purification without leaving behind secondary pollution or heavy metal resides, offering a promising alternative to less eco-friendly technologies.

Professor Dan Wang of the Chinese Academy of Sciences, one of the scientists involved, says the technique should be easy to develop on a larger scale. The construction of this material is completely metal-free, he says.

The scientists plan to improve the technique's efficiency by expanding the material's ability to absorb photons, developing antibacterial fibers, and refining the nanosheet preparation process. Wang says the technique is not intended to purify water single-handedly. "Purification needs other devices for removing heavy metal ions, adjusting pH and removing residue. We need to combine our system with others to meet water-purification requirements," he adds.

A one-step route to bioplastic monomers

Aerobic oxidation of a biomass-derived substrate [5-(hydroxymethyl)furfural; HMF] in methanol and ethylene glycol produces monomers MFDC — the methyl ester of furan-2,5-dicarboxylic acid (FDCA) — and HEFDC — the ethylene glycol ester of FDCA. These monomers are recognized as crucial for the manufacture of polyethylene furanoate (PEF) — a promising 100% renewables-based polymer that can replace polyethylene terephthalate (PET). However, MFDC production has so far been exclusively studied for dilute HMF solutions, and more desirable routes for the production of HEFDC is currently impractical because a high-yield of the monomer cannot be produced efficiently.

Now, the two monomers can be produced by a one-step, energy-efficient process developed by the research teams of Kiyotaka Naakajima at Hokkaido University (Hokkaido, Japan; www.global.hokudai.ac.jp) and Emiel Hensen of Eindhoven University of Technology (the Netherlands). The researchers previously developed a stable compound called HMF-acetal, and have now shown that 80–95% of HMF-acetal in a concentrated (10–20 wt.%) solution can be efficiently converted to MFDC and HEFDC with a gold nanoparticle catalyst. The researchers note that this method has fewer reaction steps and requires less energy than conventional processes.

This study was conducted jointly with Mitsubishi Chemical Corp. (Tokyo) and findings were published in the journal *ACS Catalysis.*

The process of optimizing glass fiber sizing is complex, laborious and time-consuming. "We expect AI to cut the development time for optimized formulations by more than half," says Axel Tuchlenski, head of Global Product and Application Development in the Lanxess High Performance Materials business unit.

In traditional product development, the complex composition of glass fiber sizings and the numerous variables when manufacturing high-performance plastics require extensive testing, the results of which can be hard to predict. AI can make an important contribution in this case by getting the most out of the available data. Supplied from thousands of measurement results from previous formulations, raw material information and a host of additional data, AI algorithms calculate forecast models for improved test configurations and parameters, enhance these models on the basis of the measurement results from each individual test, and finally propose an optimum formulation. This procedure makes product development much faster than traditional methods. ❑

Ultrafine dust has a big impact on the environment

An international study has found that coal-fired power stations emit more ultrafine dust particles than road traffic and that those dust particles can modify rainfall patterns and can, in general, have considerable impact on the climate. The study found that filtration systems of exhaust gas on modern coal-fired power stations are the main source of ultrafine particles. Ammonia is added to the exhaust gases to convert oxides of nitrogen into water and nitrogen. However, ammonia is available at the right mixing ratio for particle formation.

The study was led by professor Wolfgang Junkermann from the Karlsruhe Institute of Technology (Germany; www.kit.edu) and professor Jorg Hacker from Airborne Research Australia (Adelaide; www.airborneresearch.org.au) — a part of Flinders University (Adelaide; www.flinders.edu.au).

The study's key findings are: Modern coal-fired power stations emit more ultrafine particles than urban road traffic; ultrafine particles can harm human health; ultrafine particles can affect rainfall distribution by increasing the condensation nuclei count; ultrafine particles can be transported in layers with high concentrations for hundreds of kilometers and then lead to localized particle events. The study also found that ultrafine particle concentrations have increased continuously since modern coal-fired power stations were commissioned.

The study involved measurement flights throughout the world in small research aircraft equipped with highly sensitive instruments measuring dust particles, trace gases, temperature, humidity, wind and energy balance.

"By redistributing rainfall events, the ultrafine particles from fossil power stations can lead to drier-than-usual conditions in some places and to unusually heavy rainfall elsewhere," Hacker says.

With diameters of less than 100 nm, ultrafine dust particles have a huge effect on environmental processes. ■

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Plant Watch

Perstorp will construct new plant for sodium formate deicer product

May 9, 2019 — Perstorp AB (Perstorp, Sweden; www.perstorp.com) plans to construct a new plant in Perstorp, Sweden. The plant will increase capacity for Pergrip Run NF, the sodium-formate deicer product for airport runways. The plant will have a nameplate capacity of 12,000 metric tons per year (m.t./yr) and is due to begin operating ahead of the coming winter season (2019–2020).

Stamicarbon signs contract for urea melt and granulation plant in Russia

May 7, 2019 — Stamicarbon BV (Sittard, the Netherlands; www.stamicarbon.com) has signed a contract for license, process design package (PDP) and proprietary equipment supply for a grassroots urea melt and granulation plant for ShchekinoAzot, to be built in Pervomayskiy, Tula region, Russia. The scope of work for Stamicarbon is the complete license and PDP for a 2,000 metric ton per day (m.t./d) melt and granulation plant including supply of proprietary equipment.

Clariant Catalysts and Wuxi Xiyuan win contracts for formaldehyde production

May 7, 2019 — Clariant Catalysts (Munich, Germany; www.clariant.com) will be collaborating with its engineering partner, Wuxi Xiyuan, on two new projects to supply their joint formaldehyde production technology. The new contracts were awarded by Shandong Yushiju Chemical, one of the largest Chinese producers of phenol formaldehyde resins, and Shandong Sunny Wealth New Materials, a leading antioxidant producer in China. The producers' formaldehyde capacity is expected to be 150,000 and 130,000 ton/yr, respectively, with operations starting in 2019.

ExxonMobil proceeds with $2-billion Baytown expansion project

May 2, 2019 — ExxonMobil Corp. (Irving, Tex.; www.exxonmobil.com) will proceed with a $2-billion investment to expand its Baytown, Texas chemical plant. The expansion, expected to start up in 2022, includes a new Vistamaxx performance polymer unit, which will produce about 400,000 ton/yr of Vistamaxx polymers. The project will also include a 350,000-ton/yr plant to produce linear alpha olefins.

Covestro to expand production of polycarbonate films in Dormagen

May 2, 2019 — At its Dormagen site, Covestro (Leverkusen, Germany; www.covestro.com) has started building additional production lines for high-quality polycarbonate films. The new co-extrusion lines are scheduled for completion by the end of 2020 and will cover the increasing demand.

Linde starts up air separation unit at Samsung facility

May 2, 2019 — Linde (www.linde.com) has started up a new air separation unit (ASU) to supply 700 ton/d of gaseous nitrogen to support Samsung in Tangjeong, South Korea. This is the company's fourth ASU at the facility.

Ma'aden selects Outotec for gold-processing plant

May 1, 2019 — The Saudi Arabian Mining Co. (Ma'aden) has awarded the consortium of Outotec Oyj (Espoo, Finland; www.outotec.com) and Larsen & Toubro with an engineering, procurement and construction contract to build a greenfield mineral concentrator and gold processing plant in the Kingdom of Saudi Arabia. Outotec's share of the €540-million project is over €140 million. Outotec's delivery includes basic and detail engineering, procurement and delivery of process equipment, commissioning, start-up assistance and training services. The new gold processing plant is due to be completed in 2022.

Plinke to construct nitric acid plant in India

April 30, 2019 — KBR, Inc. (Houston; www.kbr.com) announced that its subsidiary Plinke GmbH has been awarded a contract by Gujarat Narmada Valley Fertilizers & Chemicals Ltd. (GNFC) of India to build a concentrated nitric acid plant (CNA) at Bharuch, Gujarat. Under the terms of the contract, Plinke will provide the license and engineering, as well as supply the proprietary equipment for the new plant that will produce 98.5% CNA mainly for the Indian market. The plant, which is designed for a throughput capacity of 150 m.t./d of CNA, is due to come on stream in 2021.

Honeywell UOP licenses ionic-liquids alkylation technology in China

April 26 — Honeywell UOP (Des Plaines, Ill.; www.uop.com) announced that Sinochem Hongrun Petrochemical Co., Ltd. will use UOP's Isoalky ionic-liquids (ILs) alkylation technology to produce cleaner-burning motor fuels at its refinery complex in China. Developed with Chevron U.S.A. Inc. in 2016, the Isoalky technology is the first successful liquid

alkylation technology to be introduced in more than 75 years. The technology uses ILs instead of conventional HF or H_2SO_4 acids as a catalyst to produce alkylate, a critical component for making high-octane motor fuels.

Mergers & Acquisitions

Dover acquires All-Flo Pump Company

May 8, 2019 — Dover Corp. (Downers Grove, Ill.; www.dovercorporation.com) has completed the acquisition of the All-Flo Pump Company, Ltd. business (All-Flo; Mentor, Ohio), which is now part of the Pump Solutions Group (PSG; www.psgdover.com) unit within Dover's Fluids segment. All-Flo is a growing manufacturer of specialty air-operated double-diaphragm (AODD) pumps.

Trimax Systems joins forces with Tesco Controls

May 8, 2019 — Tesco Controls, Inc. (Sacramento, Calif.; www.tescocontrols.com), a control-system solutions provider for the water and wastewater industry, has acquired Trimax Systems, Inc. (Brea, Calif.) for an undisclosed sum. Trimax is a systems integrator serving the water and wastewater market, and is also a leader in the utility, solar and renewable environmental energy industries. The transaction closed on March 31, 2019.

Metso closes acquisition of HighService Service in Chile

May 6, 2019 — Metso Corp. (Helsinki, Finland; www.metso.com) has completed its acquisition of HighService Service, the service division of the mining engineering, construction and technology company HighService Corp. (Santiago, Chile; www.highservice.com). HighService Service offers its customers a variety of services from maintenance to commissioning and remote monitoring.

Sulzer acquires GTC Technology

May 3, 2019 — Sulzer Ltd. (Winterthur, Switzerland; www.sulzer.com) has acquired GTC Technology LLC (Houston; www.gtctech.com), a technology company offering proprietary processes and systems for the production of aromatics and other petrochemicals. The enterprise value is \$39 million (CHF 39 million).

Parker Hannifin acquires LORD Corporation

April 29, 2019 — Parker Hannifin Corp. (Cleveland, Ohio; www.parker.com) announced that it has entered into a definitive agreement to acquire LORD Corp. (Cary, N.C.; www.lord.com) for approximately \$3.675 billion in cash. The transaction has been approved by the board of directors of each company and is subject to customary closing conditions, including receipt of applicable regulatory approvals. Upon closing of the transaction, LORD will be combined with Parker's Engineered Materials Group. ■

Gerald Ondrey

Modularization Finds New Roles

As benefits become apparent, the acceptance of modular process systems grows and the concept finds new opportunities

While providers of modular process systems and facilities will tell you modular builds were once a hard sell, modularization is now sought after for both traditional process systems, as well as new and novel applications. What is the reason? Aside from its many inherent benefits, including reduced costs and significant schedule reductions, the modular concept lends itself to a variety of applications across many processes (Figure 1).

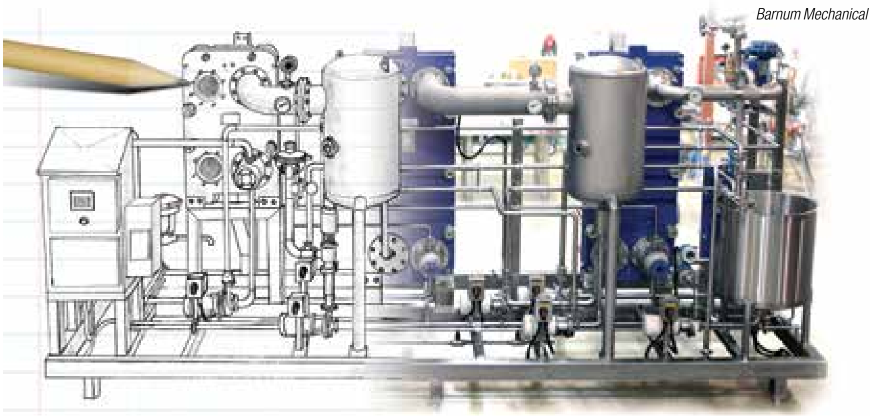


FIGURE 1. Modularization is now sought after for both traditional process systems, as well as new applications because the modular concept easily lends itself to a variety of applications across many processes. Shown here is a caustic soda evaporator skid

"The acceptance of modular construction continues to expand," says Thomas Schafer, vice president of Koch Modular Process Systems (Paramus, N.J.; www.kochmodular.com). "When we first got into the modular business, we had to overcome objections that modular construction was different and potentially would be crowded and difficult to maintain. But now we're finding that most of our clients don't have to be convinced about the benefits and quality of modular construction, as it has been widely proven, which is expanding modular opportunities."

Not only are previously conservative companies embracing modular builds, but the scope of projects is growing as well. "In more recent projects, the scope has expanded so that instead of supplying only distillation equipment, we are supplying reactors, as well as filters, compressors and other equipment modularized," Schafer continues. "So, the trend is that we are expanding the unit operations going into these systems" (Figure 2).

The big drivers for the increased interest in modular construction, according to David Funderburg, global technology manager with ABB (Cary, N.C.; www.abb.com), are the reduction of costs, schedules and risks. "Costs are reduced because you can build off site, and risk is reduced because you can pre-test and pre-document the systems, which in turn improves schedules because late changes can be managed due to the Lego-like approach of modular construction versus having a big project where any change has a ripple effect on the schedule for the entire project," explains Funderburg.

Modularization benefits

Modular construction is known to reduce costs due to the assembly-line-like building concept. In addition, the controlled workshop environment also reduces schedules, improves quality of the finished product and increases safety, which directly lead to additional benefits for owners of modular process skids (Figure 3).

Costs savings often result from labor savings, according to Ken Sipes, director of engineering for the process and mechanical group with EPIC Modular Process Systems (St. Louis, Mo.; www.epicmodularprocess.com). "Especially on large projects in an area where construction is usually performed by union craftsmen, modular projects often provide an opportunity to realize labor savings while still providing quality work performed by talented craftsmen who build to the same specifications as unionized labor forces, just under a different labor agreement."

Additional savings can be found on very large jobs where "a massive labor force would be required," Sipes adds. "In some geographical locations, a labor force of this size might be almost impossible to deliver," he says. "When labor is a limiting factor, you're left with the same amount of work to be done with a smaller crew. That crew has to work more, which means paying premium overtime wages, as well as per diems and travel expenses. However, taking a modular approach can spread the work out geographically to where the workforce is readily available, lessening the impact of those costs."

Elizabeth Manning, manager of sales with Koch Modular, says savings are also discovered because project owners don't have to employ a large project engineering staff

Koch Modular Process

FIGURE 2. This complete modular constructed process plant was designed and built for a southern U.S. specialty chemicals producer. It was a late addition to a larger project that was field constructed and the schedule was critical to catch up to the balance of plant

EPIC Modular Process Systems

FIGURE 3. The controlled workshop environment reduces schedules, improves quality of the finished product and increases safety, which directly lead to additional benefits for owners of modular process skids

to oversee the project. "They can issue a single purchase order and, ultimately, we are responsible for all of the vendors' building equipment, fabricating piping and doing electrical work. This allows the project owner to run a leaner staff than if they had to manage a field-erected plant."

The workshop environment also lends itself to reduced project schedules, as craftsmen can work indoors in a controlled environment without weather or other interference while site permits are obtained and the site is prepped. And, since skids are always pre-tested prior to delivery, it reduces installation time. "We pretest the systems and ensure that all instruments are wired correctly, calibrated and configured, all motors turn on and off and all valves are actuated to verify functionality," says Doug Cornwell, controls engineering manager, with Barnum Mechanical, Inc. (Loomis, Calif.; www.barnummech.com). "More often than not, customers request modifications or additional features during installation. This means that the installation may require more time than anticipated, but the owner's startup date isn't going to move. However, because we do testing in our shop, we are able to reduce I/O check out, commissioning and validation time during installation and

A WORD ABOUT CONTROLS

Currently, control of modular process skids is handled in one of two ways, depending upon the needs of the owner. According to Doug Cornwell with Barnum, the skids can be designed with the programmable logic controller (PLC) onboard and a self-contained program. This is often the route selected when the end user doesn't have a main PLC in the plant or when they don't want to integrate the process skid into the main control system. The skid operates via its own control panel and operator interface terminal.

The second method of control is usually employed when the end user has a PLC and they want to control the skid via the main control method. "In these cases, we supply the instrumentation and input/output (I/O) hardware according to their specifications. We put a panel on the skid with distributed I/O modules that match the brand of the PLC in the plant," he explains. "We pre-wire the skid to that distributed I/O panel, do all the pre-testing, etc., so that when we install the skid in the plant, we just bring power to the distributed I/O panel and a communication network cable and integrate our program from the skid into the owner's existing PLC program."

For companies that are building from the grassroots, skid builders often help them select appropriate instrumentation and PLCs to meet their needs and integrate the skids in the same way.

While skid manufacturers are very flexible in how their skids are controlled, the control and automation industry is looking forward to potential integration standards, says ABB's David Funderburg. "The NAMUR-led Modular Automation Initiative addresses the need to achieve an open standard interface to skid equipment," he says. "This means that end users would not be forced to use one skid vendor or one automation supplier, thus achieving true interoperability."

He suggests thinking about standardizing skid automation like a printer driver, defined by NAMUR Modular Automation as an Module Type Package (MTP). "You buy a skid that has a controller or PLC on it, as well as an interface driver (that is, MTP) that you just import into your automation system. The brand won't matter because the MTP includes pre-configured data connections, including process graphics and services, which makes it easy to import" (Figure 5).

Standardization, when achieved, will benefit skid builders, as well. "OEM skid suppliers can supply the skid with their own intellectual property in their preferred platform and the interface to it will be an open standard. This means they aren't forced to change their software or architecture to meet that of a project-specific solution," says Funderburg.

Currently, specialty chemical and pharmaceutical processors are seeking this type of standardization because it provides flexibility, allowing them to buy skid equipment to make one product, then rearrange the skids to make a different product in a plug-and-produce fashion without worrying about control and interface compatibility, he says.

Standardization would also benefit traditional oil, gas and chemical plants that have a lot of integrated skid equipment, as well, says Funderburg. "Usually there's a lot of I/O and engineering involved on projects of large magnitude," he says. "But standardization would reduce the engineering and allow users to plug in a skid and have data right away without the extra overhead of customizing interfaces to get the data from the vendor's PLC."

While it will make modularization more convenient, standardization is still a work in progress due to the conservative nature and complexity of our industry, notes Funderburg. "The standards have been released and there are pilots taking place in Europe, but there is a lag between the pilots being complete and wide-scale adoption. We are in between the technologies being proven at pilot scale and larger facilities before we can start seeing it as a standard specification for skid integration." ❑

often can reduce the on-site commissioning portion of the project from two weeks to ten days. Pre-testing allows us to absorb some of the schedule hits that sometimes occur during installation."

Experts estimate that the controlled workshop environment, concurrent building and pre-testing associated with modular construction can shave anywhere from a quarter to half the time from schedules when compared to the same project when traditionally fabricated.

As a side benefit, compressed schedules help companies get their products to market faster, says Schafer. "Some clients come to us because they are in a time crunch and need to save time in order to get to market faster and satisfy offtake contracts," he says. "They know that if they build the plant modularly, in some cases, they can be up and running six months to a year earlier than they would be if they had a large engineering company site construct the same facility."

This is important even where customer contracts aren't an issue, he adds. "Once the owners have made the decision to spend the capital, they don't want to wait any longer than necessary for a project to be completed. The faster the project is done, the faster they realize profits from it," explains Schafer.

And, in existing facilities, the modular concept helps reduce downtime, says Gregory Sandell, senior process engineer with Barnum. "We do a lot of work in existing facilities and because they're currently operating, downtime is lost revenue," he says. "Many customers in this situation find that if they go modular when they need to replace an older system with a better performing one or one that meets current standards, it can reduce the financial impact on their production schedules."

EPIC Modular Process Systems' Sipes agrees: "Think of installing processes within existing chemical plants like open-heart surgery. The heart and soul of that plant is running and has wires, power, communication and utilities connected to it and it's making product. The moment you turn off the flow to the process and start tearing it apart is the moment you stop making money," he explains. "With modular, you can do 75 to 90% of the work in the shop, bring it to the site, turn off the existing equipment, remove it, drop in the new skid, reconnect it faster because it's been pre-tested and be up and running again relatively quickly."

Additional perks of modular construction include increased safety and consistency, according to the experts. "Safety is the number one priority with our customers and this

EPIC Modular Process Systems

FIGURE 4. When a system is built in a controlled environment on a shop floor, it is inherently safer than doing this work on a job site where workers are climbing and weather and elements are a factor. It creates a safer project execution strategy

remains true when they are executing projects," says Sipes. "Modular construction lessens the amount of work done at a customer's property so their exposure goes down. Additionally, when a system is built in a controlled environment on a shop floor, it's inherently safer than doing this work on a job site where they are climbing and weather and elements are a factor. It creates a safer project execution strategy" (Figure 4).

And, for processors for whom consistency across locations is key, modular builds often provide the solution. "Some customers have facilities throughout the U.S. or globally and they want to deploy new technologies within multiple plants, but they require the same technology and the same equipment not only to provide consistent quality of the finished product, but also so that inventory and training, operations and maintenance are the same at each of those plants," says Sipes. "This can only happen when the same equipment is built to the proper codes, using consistent craftsmanship, workmanship, techniques and equipment and delivered to each of those plants in a modular fashion." For these and other reasons, modular technologies are being employed in new applications.

New opportunities

One of the newest trends is using modular skids for sustainable initiatives that reduce waste or environmental impact. "One of the hottest markets for modular skids right now is water recovery or water harvesting," says Tony Salemi, product manager with Chicago Plastic Systems (Crystal Lake, Ill.; www.cpsfab.com). "The skids recover gray or runoff water and treat and recycle it for use in flushing toilets or for irrigating landscaping. The skids include the filtration mechanisms, ultraviolet (UV) or chlorine-treatment equipment, pumps and other necessary components."

While the process is not new, modularizing it onto a skid makes it convenient to go green. "If a company wants to do this, they just order the equipment. It's delivered as a skid and installed in about a day. Then they simply collect the water and turn it on. It makes it very easy and convenient for a manufacturer to reduce their environmental impact by not using potable water to flush toilets or irrigate landscaping," he says.

Solvent recovery is another process employing modular skids with more frequency. "Everyone who manufacturers paint, adhesives or resins uses solvents and most of them want to recover these solvents at the end of the process and recycle them back to the front of the process," says Rocky Costello, president of R.C. Costello & Associates, Inc. (Redondo Beach, Calif.; www.rccostello.com). "This is being accomplished with modular batch or modular continuous distillation equipment."

Creating fertilizer from wastewater treatment is another new application for modular skids. Barnum worked with a large municipality to help develop a modular, low-temperature, commercial-scale, skid-mounted thermal hydrolysis processing unit. The mobile process was developed

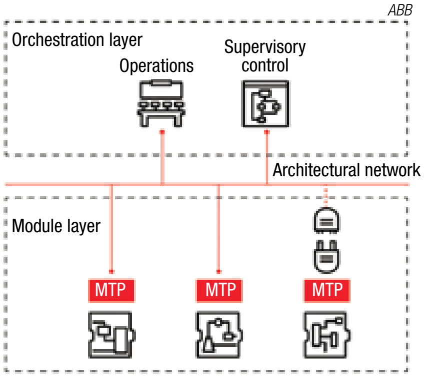


FIGURE 5. Standardizing skid automation can be thought of like a printer driver, defined by NAMUR Modular Automation as a Module Type Package (MTP)

in response to increasing demand for practical resource-recovery solutions, particularly from smaller-scale solid-waste treatment plant operators, allowing end users to create Class A bio-fertilizer product during the waste treatment process.

Another new area for modularization is in specialty and pharmaceutical processing, where the switch is being made from batch processing to continuous flow chemistry, because they are starting to realize that cost benefits can be achieved by moving from batch to continuous processing, says Costello. Often, when making the switch, these processors take a modular approach. "The cost and size of the plant is much smaller when employing continuous processing in these types of facilities and when you have smaller plants, as compared to batch processing, it's very amenable to do so in a modular fashion."

Besides reducing cost and size, it increases their flexibility. "If possible, we build the plant with modules that can move around. You may have a reactor here, a crystallizer there, a filter under a crystallizer, and so on. And, if modules are built correctly, owners can move them around into a new configuration if products change," explains Costello.

Another new market includes bio-derived chemicals and fuels, says Koch's Schafer. "Many of these products are being created by start-up companies with a great idea for a new route to a product, but who need to hire a company with chemical process engineering expertise to get them to a full-plant-constructed solution that is economical, flexible and safe. As a result, we've gotten involved in assisting several such companies with the development of these processes. And, because they want to get this new product to market as quickly as possible, modular construction makes sense as it is inherently faster."

Case in point, Koch Modular recently worked with New Jersey-based start up Primus Green Energy on its natural gas-to-liquids technology, specifically their processes for converting natural gas to drop-in gasoline and methanol via reforming, reaction and distillation unit operations. Koch assisted Primus with engineering services supporting the process conceptualization and pilot-testing phase and, later, the development of the process design package and the forthcoming detailed engineering and construction of its first commercial-scale system. ■

Joy LePree

Focus on Gas Detection

Handheld camera detects fugitive vapor leaks

The FLIR GF620 (photo) is a high-definition, handheld optical-gas-imaging (OGI) camera that is designed to help oil-and-gas industry professionals detect invisible leaks of hydrocarbons, such as methane and common volatile organic compounds (VOCs). Equipped with a 640-by-480 pixel infrared detector, the camera is calibrated to measure temperature, allowing the user to assess the thermal contrast between the gas and the background scene, and adjust it to improve visibility. The GF620 has four times the pixels of other available models, producing high-definition resolution that helps inspectors detect fugitive hydrocarbon emissions from safer distances than are possible when using lower-resolution OGI cameras, says the manufacturer. This system quantifies hydrocarbon leaks with mass or volumetric measurements and colorizes emissions for easier assessment. The QL320 software allows users to download a video from the field and post-process the footage. — *FLIR Systems, Wilsonville, Ore.*
www.flir.com

FLIR Systems

This device monitors emissions at landfills

The Landtec SEM5000 methane detector (photo) is designed for surface-emissions monitoring (SEM) at landfills. The lightweight and ergonomically designed SEM5000 uses patented laser technology with a frequency that is tuned specifically to methane, so readings are not affected by cross-gassing, says the manufacturer. The SEM5000 meets or exceeds U.S. Environmental Protection Agency "Method 21 — Determination of Volatile Organic Compound Leaks" requirements for quarterly SEM monitoring, according to the company. Unlike flame-ionization devices (FIDs), the SEM5000 uses laser technology, so there is no cross-gas effect or false readings due to the presence of other gases or hydrocarbons, as with FIDs. No flame is required — a particular benefit for sampling in a potentially explosive environment, says the company. No external gas bottle is required for operation, and the technology is accurate down to 0.7 parts per million (ppm). — *QED Environmental, a subsidiary of Graco Co., Dexter, Mich.*
www.qedenv.com

This device enables monitoring of process parameters

The multi-function DM 9600 Series Precision Manometers (photo) have a color, touchscreen display. The device can be used to measure pressure, temperature, flow and other parameters during startup, operation and troubleshooting. Five different ranges are available (from ±30 in. H_2O to ±100 psi), making the device suitable for a wide range of industrial applications. Key features include ±0.5% accuracy, flow calculations, dual thermocouple plus auxiliary input, and outputs via micro-SD card, USB and Bluetooth communications. It is designed to enable hands-free operation and has a 20-h lithium-ion battery. — *MRU Instruments, Humble, Tex.*
www.mru-instruments.com

QED Environmental

WirelessHART gas-detection device adds capabilities

The Vanguard WirelessHART gas detector (photo, p. 20) interfaces with existing networks to provide continuous detection of hydrogen sulfide and methane gases, which are among the most widely produced industrial gases. It has an expanded temperature operating range, enhanced stability across temperature ranges, improved handling of WirelessHART commands, and the capability to add additional sensors to measure other gases without changing the base unit. This versatile device can function in extreme climates and benefits from improved connectivity, while also providing a foundation on which new capabilities can be added in the future, says the manufacturer. The device also features minimal shift with changing ambient temperatures,

MRU Instruments

Note: For more information, circle the 3-digit number on p. 70, or use the website designation.

United Electric Controls

Draeger

MSA Safety

Det-Tronics

which is said to reduce the chance of false alarms, and provides faster connection to the gateway. Vanguard WirelessHART Gas Detector Version 1.2 now includes carbon monoxide, as well, among the list of gases that can be detected using the device. — *United Electric Controls, Watertown, Mass.*
www.ueonline.com

This sensor provides rapid detection of toxic gases

The multi-gas X-am 8000 sensor (photo) can simultaneously detect up to seven gases, including flammable gases, vapors and oxygen. It is applicable to a number of industries including chemical, oil-and-gas, fire services, mining, shipping, pharmaceutical and water treatment. Suitable for use in the field, the device is compact and lightweight, with an easy-to-read color-coded screen (red, yellow, green, to indicate, respectively, a gas alarm, a device-related alarm, and that the device is ready to use) that displays up to seven different gases. In the event of an alarm, the device also sounds a loud horn and vibrates palpably. It allows the user to easily switch between pump- and diffusion-mode operation, saving energy and increasing the operating time of the device without requiring factory modification. — *Draeger, Telford, Pa.*
www.draeger.com

Protect people, equipment and facilities from methane leaks

The Senscient ELDS Open-Path Gas Detector (photo), approved by FM 6325, is an open-path methane gas detector that uses patented Harmonic Fingerprint technology to ensure that it will only respond to the presence of methane. It is designed to eliminate false alarms and shutdowns. The Class 1, Div. 1, Zone 1 device is suitable for use inoil-and-gas facilities, petroleum refineries, chemical plants, liquefied natural gas (LNG) terminals, tank farms, electric power-generation facilities and more. This laser-based, Class 1, eye-safe device is said to be less prone to the effects of fog interference, and this helps to provide increased uptime availability. This methane detector is available in three path lengths: 16–131 ft, 131–394 ft and 394–656 ft, with a fast response time of 3 seconds or less. — *MSA Safety, Cranberry, Pa.*
www.msasafety.com

Minimize worker exposure during field surveys of VOCs

This wireless, Bluetooth-enabled RAE PID device is a photoionization device that pairs with a smart phone to simplify the monitoring of worker exposure to volatile organic compounds (VOCs) and preparation of field studies and reports. The device simplifies the collection of data in the field and the creation of reports. The Device Configurator companion application (app) makes data-collection intuitive, thereby reducing the administrative burden and time spent at the job site, says the manufacturer. In addition, the aggregated data can include a greater amount of contextual information, such as location, instrument traceability, comments on measurement sessions, multiple photos and more. —*Honeywell, Fort Mill, S.C.*
www.honeywell.com

Infrared line-of-sight detector monitors combustible gases

The FlexSight LS2000 Line-of-Sight Infrared Gas Detector (photo) is said to have an advanced optical field of view, a rugged housing design, simplified mount and breakthrough alignment tolerance. It provides continuous monitoring of combustible gas levels between two points at a range of over 100 m. The design helps the device to overcome many of the common installation, maintenance and performance challenges that limit the use of current line-of-sight solutions, says the manufacturer. For example, the new FlexSight LS2000 has an optics field-of-view with a 60% improvement over previous leading technology, and improved resistance to vibration, creating a more tolerant and faster alignment process, and it is certified to function over a temperature range from –55 to +75°C. — *Det-Tronics, Minneapolis, Minn.*
www.det-tronics.com

This fixed device detects gases in critical safety applications

The SensAlert ASI Point Gas Detector is a universal instrument platform for the detection of toxic and combustible gases and oxygen

monitoring in critical safety applications where personnel, processes and facilities are at risk. The sensor head accepts all Plus Series sensor technologies (infrared, catalytic bead and electrochemical). Assignable and configurable relays, together with communication options, provide broad flexibility. The device can be remote-mounted up to 100 ft from the transmitter, enabling the transmitter to be located in a personnel-accessible location while the sensor is closer to potential hazards. The device is third-party certified to IEC61508 Level 2 (SIL-2) for both hardware and software, with certification to global hazardous area and performance standards, according to the manufacturer. — *Sensidyne, St. Petersburg, Fla.*
www.sensidyne.com

Gas-detection systems alerts personnel to dangers

The Patrol Series Flashing Sounders (photo) provide alarming related to fixed gas detection. These devices are designed to alert personnel of the need to evacuate when a hazardous gas (such as ammonia, carbon dioxide, Freon, methane, chlorine and others) is present. These gas-monitoring systems are designed for energy generation, wastewater treatment, landfill applications, food-and-beverage manufacturing, refrigeration, gas production, agricultural, chemical use and storage, and other industrial applications. The system offers 80 pre-programmed alarm tones with four stages for distinctive signaling of specific events. Such devices are well-suited for environments with high ambient noise levels or when the use of hearing protection may hamper a sounder's effectiveness, or in bright environments where visual signals alone do not suffice. A single device in heavy-duty industry (>90 dB) can cover over 350,000 ft^3 (visual) and 800,000 ft^3 (audio) with an effective viewing distance of nearly a quarter of a mile, says the manufacturer. — *Pfannenberg USA, Lancaster, N.Y.*
www.pfannenbergusa.com

Suzanne Shelley

Pfannenberg USA

Honeywell Process Solutions

Greene, Tweed & Co.

Coperion

Librestream Technologies

New control system for multi-burner applications

The Kromschröder BCU 4 Series control platform (photo) for multi-burner applications is designed for directly ignited or pilot/main burners of unlimited capacity in intermittent or continuous operation, and for modulated or step-controlled gas burners. The series consists of three new models. The BCU 460 controls, ignites and monitors modulating or stage-controlled gas burners for intermittent or continuous operation, making it suitable for frequent cycling operations. The BCU 465 incorporates airflow monitoring and pre- and post-ventilation for use with recuperative burners. The BCU 480 can monitor pilot and main burners independently. The BCU 4 Series comes equipped with an ignition transformer, burner control and an embedded human-machine interface (HMI), all arranged within a compact housing. The four-digit display shows vital information, such as program status, unit parameters and flame signals. All models possess a manual mode to adjust the burner and its diagnostics. — *Honeywell Process Solutions, Houston*
www.honeywellprocess.com

Custom sealing solutions for hygienic applications

This company's family of high-performance seals (photo) are designed specifically for applications in the pharmaceutical manufacturing, analytical instrumentation and hygienic fluid handling sectors. The seals are manufactured with chemical-resistant materials to meet or exceed quality requirements, including United States Pharmacopeia (USP), FDA and ISO product standards. With low leachable profiles, these specialty compounds maintain their inert nature in highly demanding conditions. The company's Metal Spring Energized (MSE) line of seals creates a leak-free seal without excessive friction and wear by applying calculated spring force directly over sealing lips. MSE seals operate from cryogenic temperatures up to 625°F (329°C) and are available in custom sizes. — *Greene, Tweed & Co., Kulpsville, Pa.*
www.gtweed.com

Gently feed free-flowing granular media

The K-ML-BSP-150-S Bulk Solids Pump (BSP) feeder (photo) provides gentle feeding of free-flowing granular materials without using screws, augers, belts or vibratory trays to convey the material. Instead, it utilizes positive-displacement action to feed free-flowing materials, offering uniform discharge, consistent volume and gentle handling. The BSP feeder has vertical rotating discs that create feeding ducts. Material moves smoothly from the storage hopper to discharge outlet through a "product lockup zone," achieving linear mass flow. With no pockets or screws and only one moving part, the feeder is cleaned quickly, making it ideal for applications with frequent material changes. The BSP-150-S feeds at rates from 1.2 to 237 ft^3/h using five feeding discs to create four feeding ducts. It features a stainless-steel feeder body and uses a stepper motor. Two additional models are available for smaller feed rates. — *Coperion GmbH, Stuttgart, Germany*
www.coperion.com

This wearable camera includes thermal-imaging analysis

In collaboration with ecom, this company has launched the Onsight Cube-Ex wearable camera (photo) for asset analysis and safety inspections in hazardous areas. By pairing the Cube-Ex with ecom's intrinsically safe 4G/LTE Smart-Ex smartphone or Tab-Ex tablet, users can remotely control the camera, view high-definition video and thermal imaging, or capture and annotate pictures or recordings from a safe distance. The versatile design of the Cube-Ex provides flexibility for workers to wear securely on a hardhat for hands-free inspections, attach to a monopod for hard-to-reach locations, or mount to equipment to view from afar. Built-in illumination provides high-quality visuals in low-light environments. Also offered are optional cloud storage and remote expert collaboration and digital work instruction through the Onsight augmented-reality platform. — *Librestream Technologies Inc., Winnipeg, Manitoba, Canada*
www.librestream.com

Centrifugal pumps for handling abrasive media

TCT Series centrifugal pumps (photo) feature an open and rear-mounted impeller, internal anti-abrasive coating and low rotational speed (rpm), making them suitable for applications where pumps may be exposed to high levels of abrasion, such as ceramics manufacturing or distilleries. Additionally, TCT pumps feature a vortex impeller design that, compared to the traditional closed impeller, reduces the energy of the solid particles impacting the internal surfaces. — *Pompetravaini S.p.a., Castano Primo, Italy*
www.pompetravaini.com

New low-temperature seals for pressure regulators

This company has introduced a new low-temperature sealing option for its RHPS Series of pressure regulators (photo). Composed of low-temperature-resistant nitrile material, these new seals are designed to maintain a strong seal in cold climates and applications where significant cooling occurs due to high pressure drop, even in environments with extensive presence of hydrocarbons, where climate control may not be an option. The new sealing options have minimum temperature ratings of: –49°F (–45°C) for configurations rated up to 70.0 bars; –40°F (–40°C) for configurations rated up to 400 bars; and –4°F (–20°C) for configurations rated above 400 bars. — *Swagelok Co., Solon, Ohio*
www.swagelok.com

Chemical metering pumps for remote and mobile applications

The Qdos series of chemical-metering pumps (photo, p. 24) now includes a model for mobile and remote applications — with no practical access to grid electricity — that can be powered by a 12–24 V d.c. power supply. Suitable for both remote static and mobile battery-powered applications, typical uses of the new Qdos model include remote water treatment and sampling, potable water refining and on-truck pumping operations. For very remote applications, the pump is able to run

Pompetravaini

Swagelok

WMFTG

GEA Group

Inpro/Seal

Emerson

from batteries that can be recharged via solar cells, other renewable energy sources or split charge relays, says the manufacturer. The product is self-contained and does not require any additional components. — *Watson-Marlow Fluid Technology Group (WMFTG), Cornwall, U.K.*
www.wmftg.com

Safe, hygienic, in-line powder testing

This company's auger and vacuum samplers (photo) provide a reliable way to accurately take powder samples safely and hygienically while ensuring that the powder is not contaminated or damaged in the process. The auger sampler uses technology that delivers accurately controlled powder samples. The auger sampler is recommended for applications where the sampling point is near the sample destination. By contrast, the vacuum sampler is best used when the sample point is further away from the testing location. The model complies with the latest relevant global requirements and provides either a two-pot or six-pot diverting head for maximum flexibility. — *GEA Group AG, Düsseldorf, Germany*
www.gea.com

This app puts a digital twin on your device

With the new Version 2.0 of this company's ProcessApp for bulk-materials processing equipment, users have a digital twin of their machine virtually in their pocket. Operators can request spare parts directly from their machine or contact the manufacturer. ProcessApp can also be used to measure motion curves on the TSM/tsi tumbler screening machine. In addition to the tumbler screening machine, the app is now available for other machine types, such as the VRS vibration screening machine and the MSizer compact. Each new machine is equipped with its own QR code. The machine can be uniquely identified immediately by scanning the code. An embedded digital twin of the machine and an interactive drawing guide ProcessApp users to appropriate spare-parts selection. — *Allgaier Group, Uhingen, Germany*
www.allgaier-group.com

New shaft seals for screw conveyors

The AM CEMA shaft seal (photo) has been designed specifically for Conveyor Equipment Manufacturers Association (CEMA) screw conveyors. The AM CEMA shaft seal utilizes a positive air- or inert-gas- purge to create a barrier between the shaft and seal, eliminating product leakage and process contamination. Due to its non-contacting design, the AM CEMA shaft seal has no wearing parts, requiring minimal maintenance or need for rebuild kits. To accommodate shaft movement, the AM CEMA shaft seal fully articulates to allow for radial run-out and angular misalignment simultaneously. — *Inpro/Seal, Rock Island, Ill.*
www.inpro-seal.com

Simulation software speeds development of digital twins

A new release of this company's Mimic Simulation Software (photo) makes it easier for plants to develop a more accurate digital twin. New modeling capabilities, usability enhancements and tuning options will help engineers more easily create, modify and integrate dynamic simulations for process improvements across the plant lifecycle. New online stream-flow views in the latest release of Mimic significantly speed engineering changes. Users can quickly see all process elements in a single table with changeable parameters, making it possible to view and tune entire processes from front to back – all while keeping the simulated processes online. — *Emerson, St. Louis, Mo.*
www.emerson.com/mimic

Ensure complete discharge from hoppers with this vibrator

The new Vibration Bottom system (photo, p. 25) enables safe discharge of powdery, crystalline, fatty and granular bulk materials from hoppers. The lateral, imbalance vibrator sets the vibration bottom in horizontal, circular vibration. Vibrations are transmitted to the materials column via the simultaneously vibrating relieving cone inside the vibration bottom. This sets the bulk materials in motion and the level drops evenly without resulting in funnel flow or bridging. Bulk materials reach the outlet safely through the annular gap. Hop-

pers are discharged completely without leaving residue. Funnel formation and bridging in the hopper are prevented. The system can be used for virtually all bulk materials, even those that typically flow poorly. — *Azo GmbH & Co. KG, Osterburken, Germany*
www.azo.com

Process-control functionality for thermal mass flowmeters

The new PCU Series of controllers (photo) connect to thermal mass flowmeters to provide a local display of flow output. Serving as a single- or multi-channel mass-flow controller with up to four channels, the PCU controller supports multiple-unit networked operations. A large, high-contrast backlit display offers easy-to-read views of process variables and programmed setpoints for each connected device on one screen. The PCU Series offers process-control functionalities for batching, setpoint control, resettable dual totalizer and valve-override control. Gas-factor scaling allows users to set units to any fluid. Units are programmable to provide alarm status for high and low rates both visually and audibly. — *AW-Lake Co., Oak Creek, Wis.*
www.aw-lake.com

Pelletizers for high productivity and product quality

Baoli-3 dry-cut pelletizers are designed for processing both hard and soft materials. As with previous Baoli generations, the automated cutting chamber-locking system enables fast handling while supporting operator safety. The company also offers the Pearlo underwater pelletizing system for the production of spherical pellets with throughputs of up to 36,000 kg/h. Compact and modularly structured, it requires only a very small footprint in production. Electronically controlled EAC technology guarantees precise feed of the pelletizing knives during operation, thereby enabling long runtimes free of interruptions with consistent pellet quality. — *Maag, Oberglatt, Switzerland*
www.maag.com ■

Mary Page Bailey and Gerald Ondrey

Azo

AW-Lake

Fermentation Considerations and Economics

Department Editor: Scott Jenkins

Producing chemicals and fuels by fermentation of renewable feedstocks can offer improved sustainability, lower costs and greater safety compared to conventional thermal processes. But realizing these benefits depends on a careful assessment of the process economics, and an understanding of the differences between fermentation-based processes and alternatives. This one-page reference offers a brief discussion.

Process considerations

Key considerations for fermentation processes differ from those using petroleum-based feedstock.

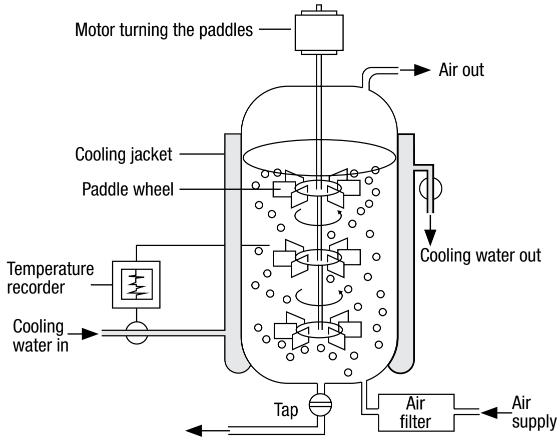
Impurities. Chemicals from fossil feedstocks have characteristic impurities that differ from those derived biologically, even if both technologies offer end products at the same purity level. For example, the feedstock for bio-based processes is often carbohydrates. These can lead to product-quality issues, such as color and odor, if not addressed during process design. Engineers for fermentation-based processes must be familiar with carbohydrate, and protein and amino acid chemistries, as well as methods for separating color and odor-causing compounds.

Separations. Separating the desired chemical product from the fermentation broth often requires different techniques and equipment than what might be found for a conventional process. Effective handling and purification of aqueous streams often dictates specialized unit operations. Key concerns include energy-efficient techniques to remove water and the ability to recycle and reuse water.

Feedstock variations. Designing a process that can handle varying inputs is a fundamental task for process engineers that impacts both capital and operating costs. The techniques for managing variations in feedstocks for bio-based processes are different than for conventional processes, and may include feedstock testing (to determine attributes), collaboration with feedstock suppliers to optimize consistency versus cost, rethinking the microorganism to efficiently handle greater variation in feedstock properties, and adjusting fermentation or other operating parameters.

Sterility requirements. Contamination is a concern in any production plant, but the manner in which it is realized for a bio-based process, and the rigor with which it must be maintained, are different. In particular, it is necessary to design, build and operate a bio-based process to exclude viable foreign microbes. This is particularly critical in fermenters and associated systems, and, depending on the product, can extend into downstream processing as well. Preventing contamination of fermentation systems is of paramount importance.

Managing weather. Large-scale fermentations can be sensitive to the effect of outside temperatures on cooling-tower capacity. Insufficient cooling capacity can ruin a fermentation batch due to temperature run-up, with consequences that can extend into downstream processing. This risk can be addressed through operating procedures that adjust process parameters to slow down the fermentation rate to maintain temperature control of the fermentation process. Fermentation plants are often constructed with minimal enclosure and exposed piping. Given their lower operating temperatures and aqueous streams, it may be necessary to account for the possibility of freezing.



Economics of fermentation

In bio-based processes, a single unit operation (fermentation) frequently replaces multiple unit operations for a conventional chemical process (diagram), so the capital cost per ton may be significantly lower (sometimes 20–40%) for bio-based process technologies than for conventional processes using fossil feedstocks — especially for mid-sized plants. Additionally, capital equipment for bio-based processes may be less expensive because they are run at near-ambient temperature and pressure and near-neutral pH, versus the more challenging conditions often required in a conventional process.

In considering capital and operating costs in fermentation processes, the questions of whether it is better to use a smaller number of large fermentation tanks (for example, one 1,000-m^3 tank) or a larger number of smaller tanks (100 m^3) should be asked. Other questions also must be addressed, including whether the process will use aerobic or anaerobic microorganisms; whether to control temperature with a cooling jacket, internal coil or external loop; and whether the process will be run as a batch or continuous process.

For separation and purification after the fermentation step, considerations include feedstock quality (more impurities at the start likely mean more effort and cost later); handling of solids, both upstream (for example, biomass pretreatment and sucrose handling) and downstream (crystallization and drying); and the properties of the target chemical (such as solubility, volatility, permeability and target purity). The net effect of these factors can be significant, potentially shifting the balance of capital and operating expenses. One process design might be better at larger scale while another is better at smaller scale. ■

Editor's note: The content for this column was adapted from the following articles: Weiss, S., Harnessing Biotechnology: A Practical Guide, *Chem. Eng.*, April 2016, pp. 38–43; and Miley, B., Riley, J. and Zelmanovich, Y. Large-Scale Fermentation Systems: Hygienic Design Principles, *Chem. Eng.*, November 2015, pp. 59–65.

Polybutadiene Production via a Solution Process

By Intratec Solutions

Polybutadiene (also known as butadiene rubber) is produced from the polymerization of 1,3-butadiene. In terms of production volume, polybutadiene is among the largest synthetic rubbers produced. This elastomeric polymer can have a variety of different properties depending on the ratio of its microstructural units and its tacticity. Most polybutadiene is consumed in the production of vehicle tires. It is also used to improve the mechanical properties of plastics.

The process

The production process discussed here is similar to the CB&I Lummus Catadiene process, integrated with a typical solution process. The process comprises four major sections: (1) *n*-butane dehydrogenation; (2) 1,3-butadiene purification; (3) polymerization; and (4) rubber molding. Figure 1 presents a simplified flow diagram.

n-butane dehydrogenation. Initially, fresh butane, recovered butane and mixed butenes are heated to dehydrogenation temperature. These components then pass through fixed beds of chromia-alumina catalysts in the reactors, where they are converted into butadiene.

1,3-butadiene purification. The reactor product is quenched for removal of polymeric compounds. The quenched gas is compressed and partially condensed. The liquid condensate, containing butadiene, is fed to a series of distillation columns, from which a butadiene-rich C4 stream is obtained. This stream is then submitted to extractive distillation in the presence of *N*-methylpyrrolidinone (NMP), used as a solvent. This step yields high-purity butadiene. Recovered butane and butenes are recycled to the dehydrogenation step, while other hydrocarbons are used as fuel.

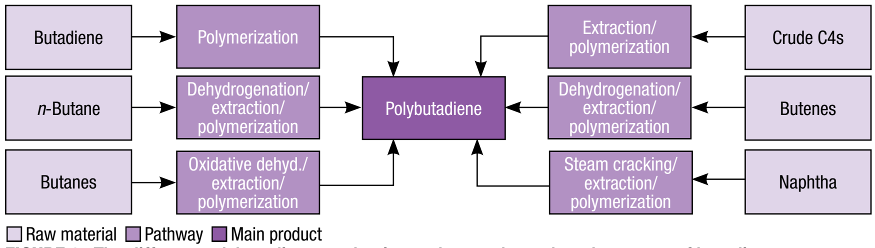


FIGURE 2. The different polybutadiene production pathways depend on the source of butadiene

Polymerization. High-purity butadiene is pre-treated for the removal of polymerization inhibitors, as well as residual impurities. The treated butadiene is dissolved in hexane and fed to a series of two continuously stirred polymerization reactors, where polymerization occurs. Polymerization is interrupted by stopping agents when the desired molecular-weight of the polymers is achieved.

Rubber molding. The polymer slurry from polymerization is passed through a flasher and subsequently through a steam stripper for hexane solvent recovery. Hexane recovered by flashing is directly recycled, while hexane recovered via stripping must be further separated from water before being recycled. A crumb-water slurry is obtained and fed to a drying step. The dried crumbs of polybutadiene are cooled with air, weighed, baled and stored.

Production pathways

Different manufacturing routes for polybutadiene are related to different sources of the butadiene used. In this context, the most typical production routes are based on butadiene produced from isolation of C4 steam-cracker fractions and dehydrogenation of butane and butenes. Different pathways for polybutadiene production are presented in Figure 2.

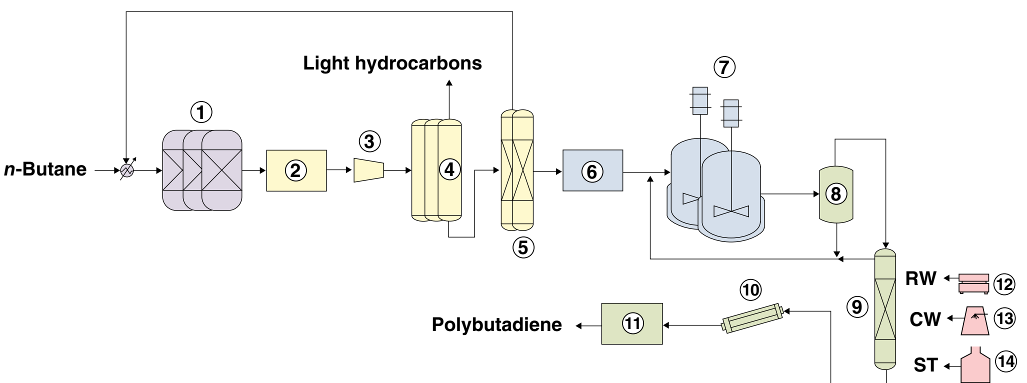
Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce polybutadiene was about $1,600 per ton of polybutadiene in the second quarter of 2015. The analysis was based on a plant constructed in the U.S. with capacity to produce 120,000 metric tons per year of polybutadiene.

This column is based on "Polybutadiene Production via Solution Process – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/polybutadiene-production-cost. ■

Edited by Scott Jenkins

Editor's note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.



1. Dehydrogenation Reactors
2. Quench system
3. Compressor
4. Distillation columns
5. Extraction columns
6. Solution preparation
7. Polymerization reactors
8. Flasher
9. Stripper
10. Dryer
11. Baler
12. Refrigeration unit
13. Cooling tower
14. Boiler

CW Cooling water
RF Refrigeration fluid
ST steam

FIGURE 1. This process diagram shows polybutadiene production via solution polymerization

Efficiency in Pneumatic-Conveying Air Filters

Paying closer attention to the air-filtration systems of pneumatic conveying operations can avoid losses in efficiency in compressed-air usage during filter cleaning

Richard Farnish
Wolfson Center,
University of Greenwich

IN BRIEF

PNEUMATIC CONVEYING PRESSURE DROP

AIR FILTERS IN PNEUMATIC CONVEYING

FILTER CLEANING

The inefficient use of compressed air in solids-handling processes, such as pneumatic conveying, can waste a significant amount of money. One of the areas that can be improved is in the air-filter cleaning system. Careful attention to the design and operation of the air-filtration system can lead to more efficient use of compressed air.

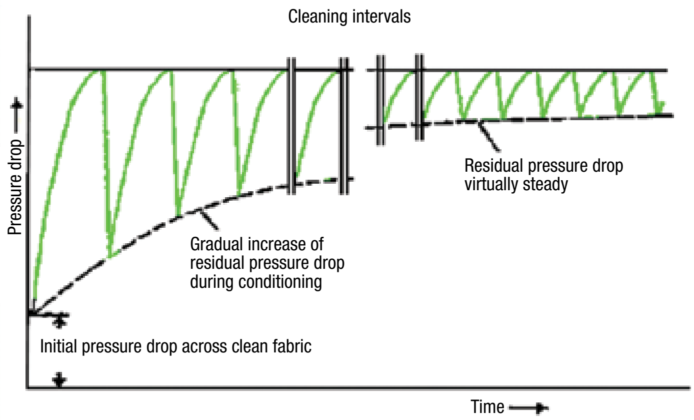


FIGURE 1. This graph illustrates filter conditioning and steady-state operation

Air-filtration systems are often underappreciated and overlooked, and are sometimes treated as "fit and forget" equipment in process plants. In cases where process conditions change, such as modifications to a pneumatic conveying system or shifts in the characteristics of the solid materials being handled, inefficiencies can result, unless corresponding changes to the air-filtration system are also considered. Changes in use or deterioration of filter efficiency — which can sometimes be present at installation for a poorly designed filtration system, and sometims develop over time as process conditions change — usually translates into higher air-consumption demands. And compressed air that is ineffectively used translates directly into wasted dollars.

To meet budget constraints or project deadlines, process engineers may unintentionally convert plant operating dollars into "thin air" through the inefficient or excessive use of compressed air. This article provides information that solids handlers should consider for maintaining the efficiency of compressed air use in air-filter cleaning systems.

Pneumatic conveying pressure drop

Pneumatic conveying systems can be troublesome to optimize without prior knowledge of the conveying characteristics of the bulk solids being handled. The importance of using such design information is slowly growing in its uptake among engineers responsible for these solids-handling systems. One of the critically important aspects is that of the pressure drop requirement for a given system that is operating at a given transfer rate with a known bulk solid material. For systems that have been designed purposely for a particular duty, an element of over-design is usually incorporated to allow for foreseeable changes in the bulk solid material. The "same" material from different sources is often actually anything but the same, and can create challenges in terms of processing and handling.

FIGURE 2. This image shows an extremely high level of solids adjacent to filters

In many cases, pneumatic conveying systems used in plants have not been optimally configured, but rather, they have been required to cope with changing plant requirements over a number of years (or more commonly, decades). Taking into account wear on the equipment, adjustments to pipe routes and changes in the bulk solid material, these conveying systems are often operating on a "knife edge," where small increases in pressure drop throughout the system (for a variety of reasons) can often lead to unexpected downtime and loss of product.

One aspect of pneumatic conveying systems that can contribute to these problems is the air filter on the receiving silo or bin. When a pneumatic conveying system becomes prone to blocking, one of the first remedial actions plant engineers might take is to increase the airflow. This response brings with it a raft of other unintentional negative consequences, not least of which is excessive air consumption.

Air filters in pneumatic conveying

How can the air filter contribute to excessive air consumption? In understanding the answer to this question, it is important to realize that a "value engineering" approach may have been taken with these conveying operations. Value engineering refers to the idea of reducing costs for equipment that is not considered to warrant an adequate budget. Unsurprisingly, the "out of sight, out of mind" approach to air-filter procurement often results in installed units that may exhibit marginal performance from the moment they are commissioned. The concept of including an element of overdesign for the pneumatic conveying system usu-

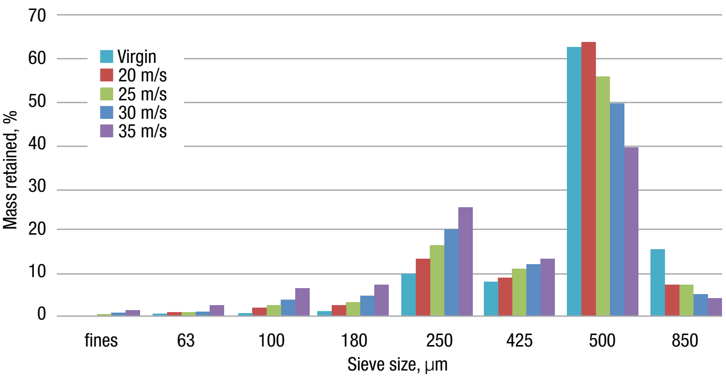


FIGURE 3. Shifts in particle-size distributions can result from excessive air velocities in a pneumatic conveying pipeline

ally does not apply to the filters.

The types of filters employed in reception vessels can be broken down into two basic styles: mechanically activated and reverse-jet pulse. The former should be applied to batch transfer processes where a significant downtime occurs between loading cycles. In these cases, there is an adequate period within which stimulation of the filters (bags or socks) can be undertaken. The filter media used in such systems relies predominantly on the surface capture of particles, rather than in-depth capture. Therefore, they can be dislodged with relatively high efficiency. The sequencing and operating duration are usually wholly dictated by the operational timing for the process. Such filters can be robust and offer good service. However, these systems are not suitable for continuous processes (where no downtime occurs for cleaning functions).

Continuous processes typically use reverse-jet cleaning systems. In these cases, the cleaning cycle is often completed within 20 ms. For such systems, multiple filter elements are secured into a top plate of the filter housing and a pulse of compressed gas is directed down into multiple or single filter elements. The cleaning function is achieved through the pressure pulse accelerating the filter media, which will decelerate abruptly once it has reached its limit of expansion. This results in the onward loosening and detachment of captured particles ahead of the gas volume flow, which serves to transport particles out of and away from the filter face. As the pulse travels down and dissipates progressively through the filter media, energy is lost while, correspondingly, a degree of gas volume increase occurs. Thus, the cleaning mechanism down through a filter changes. Gas reservoir pressures used in such systems can range from 3 to 5 bars and the pressure applied should be matched to the duty and nature of the filter media. In fact, this style of cleaning can also be applied to batch processes in which sufficient time may exist for a gas back flush to remove particles captured in-depth.

Although many equipment suppliers employ commonly sourced filters, major differences can be found in the methods for applying the pressure pulse. And since compressed gas is equivalent to money in processing operations, judicious usage should be the order of the day.

The most basic arrangement employs a single external air reservoir and multiple air distribution tubes (each serviced by a dedicated solenoid). Such arrangements would typically see the distribution tube passing across the inlets of multiple filters, with the bleed hole in the pipe centered above the inlet of the filter. The effectiveness of this arrangement can vary considerably depending upon whether the filter elements have been correctly sized for a given peak air flowrate and, of course, the nature of the particles being captured. As mentioned previously, the optimal use of the pressure pulse capability of a system is key to the capture-and-release characteristics for a given reverse-jet arrangement. Performance can be enhanced through the use of a nozzle at the bleed hole in the distribution pipe. Such arrangements not only focus and preserve pressure, but act as eductors, drawing additional air into the filter. The combination of minimal pressure loss and enhanced gas volume within the filter assist with particle disengagement and mobilization from the filter.

Filter cleaning

Key to the longevity of a filter is ability for the compressed-air reservoir to have been sized to cope with air requirements that will usually increase over time, as the filter progresses through its lifecycle. When newly installed, the filter will exhibit a low initial pressure drop, which will progressively increase over a series of "cleaned-to-loaded" cycles of operation. This initial increase in pressure drop will usually stabilize to give a relatively steady "clean" condition as the filter becomes conditioned with embedded particles (Figure 1).

Over time, the mass of irretrievably embedded particles will start to increase to a point where the "dirty" pressure drop contribution of this material begins to dominate that of the mobile particles. During this end-of-life phase of the filter, the difference between the "clean" and "dirty" conditions will decrease. Either through strategic planning or neglect, it is not unusual for filters to be driven to this deteriorating condition.

If the filter cleaning cycle is controlled on a timed basis, then the filter may begin to approach a blinded condition, which gives rise to high pressure drop (sometimes to the extent that the filter housing can be subject to overpressure). This can, in turn, strain sealing gaskets. If the system is controlled on a pressure-drop measurement, then the increased frequency of pulses may match or exceed the re-pressurization capability for a marginally sized air reservoir. This leads to diminishing pulse pressure, and consequently, to reduced cleaning efficiency. This latter effect tends to lead to a runaway deterioration of the serviceability of the filter.

Process variables with strong influence on the ability of a filter to capture (and equally importantly) release particles include particle concentration in the air, and face velocity that develops during operation. Various factors can bring about changes in both these variables. It is fairly common for process plants to change the products that are being manufactured, but sometimes the changes in product have unexpected side effects. An example of this could be a plant whose process-control philosophy is based on measurements of weight, but the plant has changed to a substantially lower-density product. In such a situation, inventory levels in pneumatic receiving bins can increase considerably until the requested weight is achieved. This can bring material levels to a point where there is direct interaction with the incoming charge, creating excessive high dust loadings in the immediate vicinity of the filters (Figure 2).

The net effect is invariably a shortened time period between cleaning cycles (when operating on pressure-drop triggering) and hence much higher compressed-air consumption. On the other hand, an excessive face velocity (embedding particles more strongly) can be generated if factors such as blowdown at the end of a dense-phase batch transfer occurs. Under such circumstances, the filter area may be found to be inadequate if this effect of increased air volume has not been fully taken into account when the filter system was designed and specified. Shifts in particle-size distribution can also be an outcome of the use of excessive air velocities in a pipeline (Figure 3). ■

Edited by Scottt Jenkins

Author

Richard Farnish is a senior consulting engineer at The Wolfson Center for Bulk Solids Handling Technology at the University of Greenwich (Chatham, Kent ME4 4TB, U.K.; Phone: +44 0208 331 8646; Email: R.J.Farnish@greenwich.ac.uk). The majority of his time at The Wolfson Center is spent undertaking consultancy activities for a wide range of industrial sectors, although he is also involved in the delivery of undergraduate lectures and short courses to industry. A large proportion of his work is linked to troubleshooting bulk solids processes that are underperforming as a result of equipment design issues or product quality problems (segregation, agglomeration, attrition and so on). His research interests relate to optimizing dry-filtration systems. Farnish has worked at the Wolfson Center since 1996. He is a chartered mechanical engineer and a member of the Institution of Mechanical Engineers in (CEng MIMechE) in the U.K.

Part 2

Minimizing Risk for Combustible Dust Explosions

By focusing on ignition sources, such as static discharges, and housekeeping, facilities handling solids can minimize their risk for combustible dust explosions

James Grimshaw
Hoerbiger Safety Solutions

IN BRIEF

- DUST 'PENTAGON'
- AREAS OF RISK
- PARTICLE SIZE
- PRIMARY AND SECONDARY EXPLOSIONS
- IMPERIAL SUGAR EXPLOSION
- PREVENTING STATIC DISCHARGE
- PREVENTION CONCEPTS

Dust explosions in industrial facilities can cause injuries, destruction of property, and — as history will attest — unfortunately, fatalities. A U.S. Chemical Safety and Hazard Investigation Board (CSB; Washington, D.C.; www.csb.gov) report conducted in 2006 identified 281 combustible dust incidents between 1980 and 2005 that killed 119 workers with injuries sustained to 718 others, along with several damaged facilities. In the U.K., the government agency Health and Safety Executive (Merseyside, U.K.; www.hse.gov.uk) recorded 303 dust explosions over a nine-year period, and German records demonstrate 426 similar incidents over a 20-year period. Unfortunately, tragic incidents like these continue to cause significant business interruptions and loss of lives.

Given that such hazards exist within industry today, it is critical for plants to focus on areas where they significantly reduce the risk of dust explosions. These include close attention to good housekeeping practices, strict adherence to maintenance practices, and the identification and elimination of ignition risks for combustible dusts. This article provides information on the potential causes of dust explosions and on methods to minimize the risk of such incidents occurring.

Dust 'pentagon'

Dust explosions within hazardous-area processing environments are not a new danger, nor is static charge being a potential source of ignition. The earliest recorded dust explosion was at Giacomelli's Bakery in Turin, Italy in 1785, where flour dust generated during normal operations came into contact with a mounted lamp. Flour can become

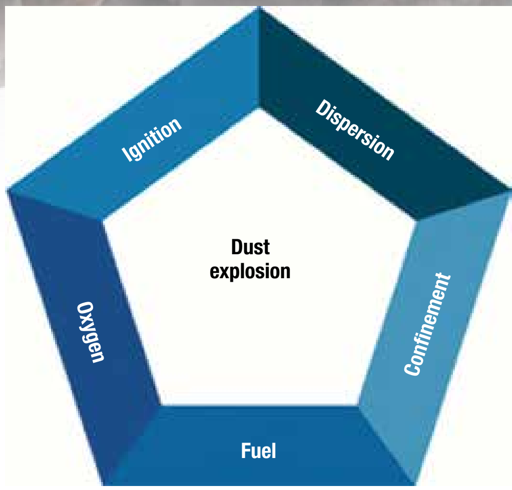


FIGURE 1. Confinement and dispersion are the two elements specific to dust explosions that make up the dust fire pentagon

combustible if it is too dry and builds up a static charge. The bakery owner was recorded as saying that the flour was the driest seen in the bakery that year. A dispersed cloud of flour originated when flour from the upper portion of the warehouse dropped to the confined warehouse below. The resulting explosion that followed injured both the worker shovelling flour into an open flame and a boy who fell from scaffolding, as a result of the flames blowing out windows onto the street. What this incident inadvertently demonstrated, apart from the violent and volatile nature of a dust explosion, was an archetypal insight into the "dust explosion pentagon."

Five elements are required to intiate a dust explosion. Beyond the fire triangle (fuel, oxygen, heat source), a dust explosion requires two additional elements, in the form of dispersion of dust particles in the right con-

centration and the confinement of the dust cloud itself (FIgure 1). Dispersed airborne dust burns more rapidly, and confinement allows for pressure build up. Having these two additional elements in place, along with the three elements of the original fire triangle, increases the likelihood of a dust explosion.

By definition, a combustible dust is any fine material that has the ability to catch fire and explode when dispersed in air. By their very nature, dust explosions emit an energetic force, creating powerful pressure waves that can cause significant harm to personnel and damage to facility structures and equipment. Dust explosions can also generate intense heat inside the dust cloud and can cause structures to fall, creating additional risks for plant personnel.

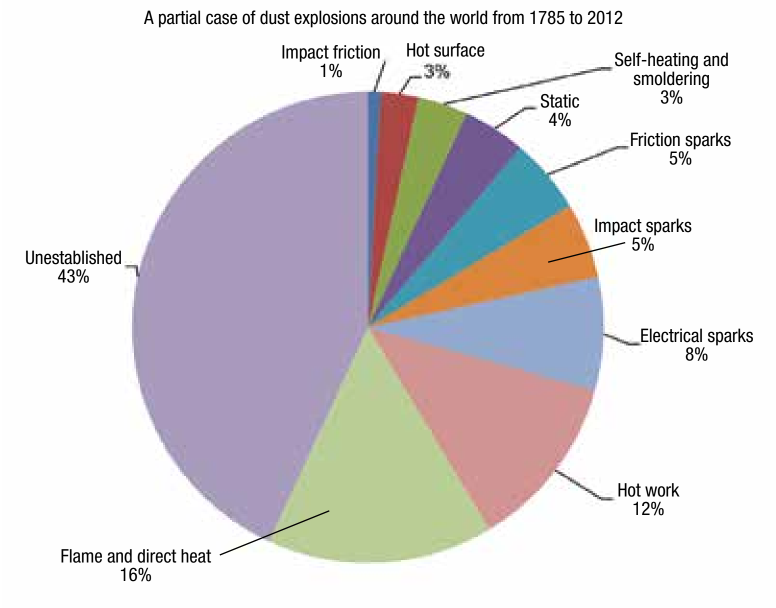


FIGURE 2. A wide range of ignition sources exist for dust explosions in process plants

Areas of risk

Dust is a hazardous byproduct in many industries in which handling powders is involved. This includes companies engaged in a wide range of sophisticated manufacturing processes. Dust explosions can occur in any industry handling combustible dusts, including (but not limited to) the following:

- Coal
- Wood
- Waste recycling (paper)
- Agriculture
- Chemicals
- Metal processing

FIGURE 3. Dust explosions often have primary explosions, which occur in confined process equipment, and secondary explosions, which ignite material dispersed by the initial explosion

Over half of dust explosion incidents can be attributed to one of these four industry sectors: food products, wood products, chemicals and metals. The average dollar loss per explosion incident in a typical year is $3.4 million.

The National Fire Protection Association (NFPA; Quincy, Mass.; www.nfpa.org) Standard 654 (Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids) defines dust as “A combustible particulate solid that presents a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape.” Many organizations are uninformed and unaware that their processes can produce an atmosphere that can be explosive, and as a result, dust can be produced by a seemingly innocuous consequence of their usual manufacturing process.

There are a number of primary ignition sources that can trigger a dust explosion (FIgure 2), including the following:

- Electrostatic ignition
- Friction
- Electrical arcing
- Hot surfaces
- Open flame
- Self-ignition

FIGURE 4. Dust explosions, such as the one shown here in Port Wentworth, Georgia, can create devastating destruction

TABLE 1. MINIMUM IGNITION ENERGIES, JOULES	
Zinc	200
Wheat flour	50
Polyethylene	30
Sugar	30
Magnesium	20
Sulfur	15
Aluminum	10
Epoxy resin	9
Zirconium	5

Particle size

Dust explosions occur when a dispersed combustible material is present in a sufficiently high concentration. Therefore, an explosion hazard exists whenever dusts are produced, stored or processed, and whenever these materials become airborne. When the product being processed is considered combustible and has an appreciable portion of fine material, the potential for having an explosion increases dramatically. Fine powders with low minimum ignition energies (MIE) will regularly reach the minimum explosive concentration (MEC) along conveying systems and may be at risk of combustion by several sources of ignition. One such ignition source is electrostatic discharge.

The MIE required to ignite any given powder depends on the fineness of particles, with the lowest MIE values tending to relate to very fine particles (Table 1). In situations where the MIE for a dust material is above 10 Joules, and no flammable gases or vapors are present, taking special measures to minimize static electricity is usually not necessary. However, precautions could still be necessary with conductive plant equipment capable of storing high levels of static charge, to minimize electric-shock risks for operators. In the chemical and pharmaceutical industries, MIE values required for ignition are often relatively low (especially in flammable dust-vapor hybrid atmospheres), while in the food industry, MIEs are usually somewhat higher.

The ease of ignition and severity of combustible dust explosions are typically influenced by particle size. Finer particles are more explosive than coarse particles because they have larger surface areas relative to their weight, allowing them to rapidly react with oxygen when dispersed in air and ignite (Table 2).

In NFPA Standard 654, dusts are defined as solid particles with particle diameters of 420 microns (μm) or smaller. For perspec-

tive, the particle size of table salt is around 100 microns.

Primary and secondary explosions

One of the main dangers of a dust explosion occurs when combustible dusts ignite and cause a chain reaction with other dusts. Dust explosions create their own self-sustaining domino effect, which continues as long as fuel exists. A secondary explosion occurs when dust accumulated on floors or other surfaces is lifted into the air and ignited by the primary explosion. The primary explosion liberates dust from surrounding surfaces (including beams and ledges), causing them to be suspended in air and dispersed. The secondary explosion propagates from the resulting dust cloud. Secondary explosions occurring when the structural integrity of the facility may already be compromised can result in catastrophic results.

Primary and secondary explosions often occur together, allowing for transitions from fire to multiple explosions and vice versa. In many cases, a primary explosion occurs inside a process vessel, such as a sieve, dryer, mixer, conveying system or silo (Figure 3). It is within these confined environments that the five elements of the dust explosion pentagon are met. The resulting impact of the first explosion usually ignites the second. Unburned fuel from the primary explosion is ejected by the blast outside the enclosure, causing dust to become airborne, where it is susceptible to ignition and is capable of triggering a secondary explosion.

A secondary explosion can be more destructive than the primary due to the increased concentration of dispersed

TABLE 2. PARTICLE SIZES OF SOME COMMON COMBUSTIBLE AND NON-COMBUSTIBLE MATERIALS (IN MICRONS)

Talcum powder, red blood cells, fine silt, cocoa	5 to 10
Pollen, milled flour, coarse salt	44 to 74
Table salt	105 to 149
Cornstarch from Port Wentworth facility storage silo	10
Powdered sugar product from the Port Wentworth facility	23
Ganulated sugar product from the Port Wentworth facility	286

FIGURE 5. The Imperial Sugar explosion resulted in 14 fatalities, most of which occurred during the secondary explosion and fire

combustible dust and stronger ignition source. The resulting shockwave of an initial explosion will damage and often rupture the self-contained vessel where the initial blast occurred, allowing the explosion to propagate through the plant.

Imperial Sugar explosion

The explosion at the Imperial Sugar refinery in Port Wentworth, Georgia in 2008 provides and illustrative example of a dust explosion and highlights the devastating effects that any dust explosion can have on people, businesses, communities and the economic climate (Figures 4 and 5). The incident claimed the lives of 14 workers and critically injured 36 others. A year before the blast, in 2007, the company had produced 1.3 million tons of sugar, making it one of the largest sugar refineries in the U.S. A series of violent sugar dust explosions obliterated the site, with 12% of the 160-acre facility completely destroyed. According to the subsequent CSB investigation, all 14 casualties from the blast were "most likely the result of the secondary explosions and fires."

Prior to this destructive incident, the Port Wentworth facility had operated for more than 80 years without experiencing a devastating dust explosion. However, the plant had a history of long-standing problems of sugar dust and spilled sugar in the packing buildings and silo penthouse between 1970 and 2007. It is likely that, although conditions suggested that an incident should occur, the sugar dust never accumulated to levels above the MEC before the event. It seems to have been just fortune that dust from spilled sugar never reached levels where the concentration was high enough for an explosion to propagate through a plant until the incident. Internal correspondence documented the amount of spilled sugar as "knee deep" in some areas of the plant. Two months prior to the incident, an internal inspection showed that tons of sugar were accumulating on the floor of the facility. This provided much of the fuel for the secondary explosions.

At the Port Wentworth site, granulated sugar was stored in three 100-ft silos and then conveyed into packing buildings, where it was packaged for distribution. The primary dust explosion occurred inside the enclosed steel conveyor belt used to transport granulated sugar under silos 1 and 2. Airborne combustible sugar dust accumulated above the minimum explosible concentration inside the unit, and this triggered huge secondary explosions and fire throughout the packing buildings. In the aftermath of the incident, the CSB reported that for many years, granulated sugar on these conveyors was exposed to possible contamination from debris that could fall into the sugar. As a result, Imperial Sugar installed a stainless-steel frame to enclose each belt assembly to protect granulated sugar from debris and contamination. These panels were able to be removed for cleaning operations, but were not equipped with a dust-removal or explosion-venting system. The stainless-steel enclosures essentially confined the sugar such that sugar dust was able to accumulate to a potentially explosive concentration above the MEC within the conveyor. An overheated bearing was determined to be the likely ignition source, and the explosion was triggered in that way. In addition, multiple other potential dust-ignition sources were identified inside the enclosure.

Imperial Sugar CEO John Sheptor stated at the time that "accumulated sugar likely acted like gun powder," and called combustible dust "a silent risk that needs to be addressed." In the 1925 book "The Dust Hazard in Industry," author William Gibbs concluded that "Sugar, dextrin, starch and cocoa are the most dangerous," in terms of dust explosions in industrial facilities, with sugar being exceptionally so. "Sugar ignites when projected as a cloud against a surface heated to below red heat, and when ignition has taken place, the flame travels throughout the dust-cloud with great rapidity," Gibbs wrote. In the wake of the Imperial Sugar explosion, The Occupational Safety and Health Administration (OSHA; Washington, D.C.; www.osha.gov) cited the company for 108 instances

of "willful violations related to the combustible dust hazard, including the failure to clean up spilled dust and not using appropriate equipment or safeguards where combustible dust is present." At the time, the proposed fine of $8.7 million for the sugar refinery explosion was the third largest in history for an industrial safety incident.

Preventing static discharge

In manufacturing and handling process industries involving flammable and combustible atmospheres, the threat of static electricity is ever present. There are certain types of dust-handling plant equipment in which static electricity is readily generated. These include mills, conveyor belts and pneumatic conveying systems. In potentially explosive atmospheres, the amount of energy contained in spark discharges from plant equipment, and even from people, may be sufficient to ignite many fine dusts produced during handling of loose solids, such as powder, granules, pellets and flakes. Electrostatic charging of isolated plant equipment or materials is likely when moving dusty materials in quantity. It is fundamentally critical to take necessary precautions to prevent discharges that are powerful to cause ignition of a dust cloud.

All potential sources of internal and external static discharges from process equipment situated in zoned and classified areas must be accounted for and managed in the appropriate way. If they are not sufficiently bonded and grounded, isolated components in conveying and dust collection systems are capable of holding large amounts of static electricity. Isolated components usually result from design oversight, or after maintenance teams reassemble fittings without re-establishing static bonding connections. Pipes, valves, blowers, hoppers and other components engaged in powder transfer processes can be isolated from each other due to the insulating properties of parts like rubber gaskets, or through general wear and tear. The most secure means of preventing charge build-up is to bond and ground components to a reliable verified earth.

Although the generation and accumulation of static electricity is invisible and discrete, it holds a very real possibility of a potential discharge and the risk of igniting combustible atmospheres. To prevent electrostatic discharges from igniting combustible dusts, companies should conduct risk assessments of their processes and equipment to ensure all potential sources of static ignition are identified and managed correctly.

Each explosion threat presents its own unique set of challenges. The variables involved, from the combustible material, ignition source, process vessel, operational procedures and environmental conditions, all impact the degree of risk and the severity of the consequences of an explosion. There are a number of practical solutions to consider in order to safeguard the plant, people and processes, such as grounding and bonding, explosion venting, suppression and isolation, among others. Static grounding and bonding systems

FIGURE 6. A static-electricity grounding system can reduce the risk of dust explosions. In the conveying system shown above, the numbers represent parts of the system that could be at risk for isolation

are designed to eliminate static as an ignition source before combustible material is allowed to ignite. In safety terms relative to the dust fire pentagon, removing the ignition source eliminates one of the key elements required for an ignition.

Despite the potential for extensive loss of human life, damage to facilities and downtime in production, history has shown that necessary actions and preventive measures have not always been taken. Of course, it is not always possible to completely eliminate the risk of dust-related explosions, but the prevention is critical.

The nature of a powder processing operation means that the generation of static electricity is to be expected in all parts of the system because of the movement of the particles through equipment. Therefore, regular maintenance is required to stop material from clogging up the machinery. Regular disassembly for cleaning and maintenance can result in bonding connections being missed or not made correctly when the equipment is reassembled. Vibration and corrosion may also degrade assembly connections, so it is imperative to ensure that no parts in the assembly become isolated from a true earth ground. The most effective way of ensuring that the complex equipment used in powder-processing operations cannot accumulate static electricity is to provide a dedicated static grounding solution that is capable of monitoring the ground connection to components at risk of isolation (Figure 6). Such a solution is able to prevent the flow of product and alert personnel to a potential hazard should a component lose its connection to ground. This is especially important if the ground connection point to the equipment is not readily visible, or isn't easily accessible (for example, grounding clips). Powder-processing equipment presents more of a challenge compared to standard applications, because there are metal parts that can make up larger assemblies that can be electrically isolated from each other. The risk of removable sections becoming isolated conductors will occur if each section does not have a sufficiently low path to ground to safely dissipate charge, and also if the correct reassembly of equipment after cleaning, between operations and regular examination of bonding straps between the metal pipework and duct sections by plant personnel is not routinely carried out.

Other prevention concepts

Additional areas of consideration to prevent dust cloud accumulation in solids-handling facilities include the following:

1. Maintain a plant in a leak-tight condition (fix damaged seals, tighten loose bolts)
2. Reduce labor involved in cleaning by designing plants within the minimum number of horizontal ledges where dust can settle
3. Electrical plant equipment may be at risk of overheating if dust deposits settle
4. Introduce technical measures to safeguard against an explosion

One of the most important risk-mitigation measures is maintaining a clean working environment. If dust deposits are allowed to accumulate, they can provide fuel for a secondary explosion.

To prevent uncontrolled static discharges posing a fire and explosion hazard in powder-processing operations, a thorough static audit conducted by qualified personnel should be carried out. For situations where potentially isolated components are identified, dedicated grounding equipment should be installed to monitor and control the release of static electricity, thereby removing a primary source of ignition in combustible dust atmospheres.

Given that such hazards exist within industry today, good housekeeping, strict maintenance practices, and ignition risk identification and elimination are paramount in preventing a dust explosion. ■

Edited by Scott Jenkins

Author

James Grimshaw is the marketing manager of Newson Gale Ltd. (Omega House, Private Road 8, Colwick, Nottingham, NG4 2JX; Phone: +44 (0)115 940 7537; Email: james.grimshaw@hoerbiger.com; Website: www.newson-gale.co.uk) Newson Gale is part of the Hoerbiger group. Grimshaw's background and experience within the business of safety stems from working in business-to-business environments with organizations that provide technologies used to protect assets and its people.

Professional Calibration Supports Operational Excellence

Apart from ensuring the conformity of the process and the quality of the product, professional calibration, first and foremost, improves the quality of the process

Dimitri Vaissiere and Pia Höfflin
Endress+Hauser

IN BRIEF

At many plants in the chemical process industries (CPI), measurement instrumentation is usually calibrated during scheduled maintenance downtimes. This basically means that metrological requirements are regarded as secondary to operational needs. The objective seems to be to produce a complete set of calibration certificates to pass the next audit again. Although this approach seems to be practical, in fact, it misses the point: professional calibration management is aimed at safe and efficient production processes and optimal product quality.

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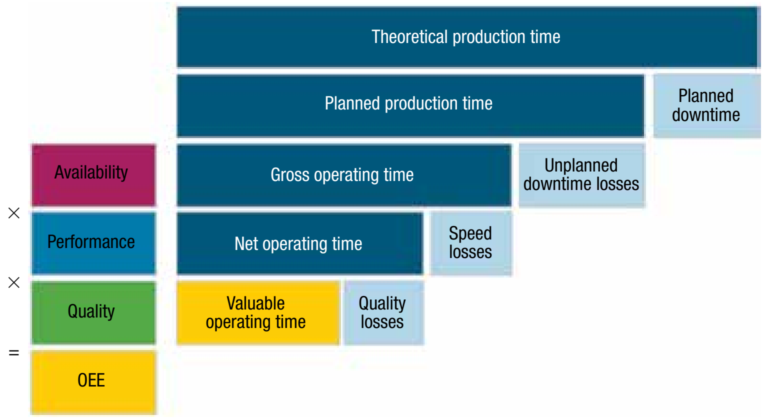

FIGURE 1. Availability, performance and quality are the three quantifiable components of the overall equipment effectiveness (OEE)

Why calibrate?

Calibration should not be considered primarily as a means to obtain a certificate for regulatory reasons. Calibration is much more than just a question of compliance. Rather, it affects the overall equipment effectiveness (OEE), and lacking or inadequate calibration might result in increased expenditures.

Availability, performance and quality are the quantifiable components of OEE (Figure 1). All of these three can be affected by incorrect measurements. Availability may be impacted where failing devices might result in shutdowns. Performance suffers when drifting measurements call for corrective actions time after time. In addition, incorrect measurements may be responsible for waste in raw materials or production loss.

Of course, process instrumentation does not come for free. There are the inevitable direct costs of maintenance and calibration, for example (Figure 2). But on the other hand, apart from the above-mentioned issues arising from poor measurements, working with inaccurate readings can cause unnecessarily high consumption of energy and raw materials.

To avoid the numerous details of common textbook knowledge we would like to simply summarize the purpose of calibration as follows, just to provide an operational definition: those who calibrate a measurement instrument are determining whether and to what extend the measured value deviate from the reference value given by a measurement standard. If the deviation exceeds the tolerance — generally called maximum permissible error (MPE) — the instrument likely needs to be adjusted, repaired or replaced. This applies to all types of measuring devices, whether they measure physical quantities, such as flow, pressure and temperature, or chemical parameters, such as pH, conductivity, dissolved oxygen and so on. The calibration method for both of these

FIGURE 2. Maintenance and calibration are inevitable costs associated with instrumentation

groups and even for each individual measuring principle is different, but this is a secondary aspect. What all instruments have in common and what can be regarded as the actual objective of calibration is that we have "to ensure their [that is, measuring instruments] continuing fitness for their purpose," as per ISO 9001:2015 §7.1.5.

A sound approach to calibration

As already stated, calibration is not primarily about obtaining a certificate. It should support the way to the optimal OEE. A reasonable approach to calibration is illustrated in Figure 3.

The most decisive aspect of a proper calibration strategy is the criticality of each measurement point. The responsible persons, for instance calibration or maintenance managers, need to ask: what does my production process require? They should pay especially close attention to measurement points that are critical for a smooth-running process, safety, energy consumption and product quality. This also applies where an inaccurate analysis value would cause a valuable product batch to be discarded.

Another important consideration is related to instrument tolerance. Although there are measurement points where the acceptable measurement error is relatively high, there are others where this is not the case. This problem is addressed through the specification of the MPE that should be defined with respect to the process requirements.

In most cases, the determination of the MPE reflects a complex set of considerations, which in turn means that it cannot be solely the responsibility of the maintenance manager but should involve other experts as well, such as factory engineering, quality assurance, safety and so on. It is essential that the maintenance manager, or whoever else oversees the calibration or recalibration, involves the process owner or plant operator in order to incorporate their know-how and experience regarding the process. Quality management can also make a valuable contribution on a consistent basis. After all, calibration is an important part of quality assurance.

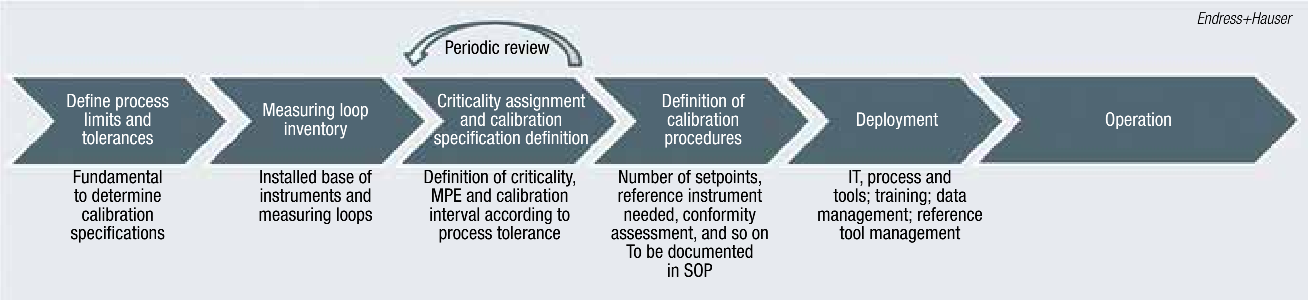

FIGURE 3. An approach to calibration is outlined here

Calibration intervals

In many instances, maintenance managers, when inquiring about the appropriate calibration intervals, expect a standard answer that applies equally to every instrument in the installed base. While this corresponds well to the scheduled maintenance and service downtimes, it does not support the overall goals of calibration. Even the relevant standards do not specify exact intervals. Instead, they merely suggest, in the words of ISO 9001, that "measuring equipment shall be calibrated or verified, or both, at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards." Consequently, the organization is responsible for determining and establishing suitable calibration intervals.

When determining the appropriate calibration intervals, it is very important to realize that a "one fits all" strategy does not work. To determine the adequate interval for each instrument, the following aspects must be considered:

- Device type and its sensitivity to drift
- Criticality of the measuring point
- MPE
- Aging of instrument
- Individual process and environmental characteristics

Consequently, calibration intervals cannot be the same for all cases and cannot be static over the instrument's lifetime.

Indeed, it is not uncommon for older instruments to tend more towards drifting. Also, process conditions, such as a high-temperature environment that impacts electronic components, can also cause the measurements to be less stable. In chemical processes, it is often the products themselves that put a heavy strain on the instruments, for example, when they are highly corrosive. This clearly shows that only dynamic intervals can factor in all those aspects. In that respect, measured values during calibration shall be taken into consideration and not only the conformity statement, as they reflect the behavior of the measurement instrument.

Setting the calibration frequency for each measuring device is a matter of risk management in finding the optimal balance between cost and risk. Calibration is therefore not a pure burden, as it is perceived by many plant operators. Instead, it represents more of an opportunity, because at the end of day it leads to improved and more reliable processes.

Performing calibrations depends on an even deeper understanding of the installed base. Although that should be obvious, it's often not the case.

Interval optimization

Keeping a comprehensive inventory and description of each and every instrument and measurement point is the first stage of the process. Once the installed base of instruments has been inventoried and documented, including the required calibration intervals, it is still too early to begin the calibration itself. Of major significance for proper calibration processes are the standard operating procedures (SOPs), which must be created, reviewed and if necessary, modified. This is not only important for the audits. What must be determined is the number of respective calibration points, as well as the measurement uncertainty that can be tolerated. Which calibration method will be selected? Which reference instruments will be used? Which requirements regarding conformity should be considered? Within the entire calibration process, there is often a lot of hidden potential for increasing efficiency. The logistics and the workflow management related to calibration should not be underestimated. Furthermore, calibration managers must make sure that the employees who will be carrying out the actual calibration are thoroughly trained.

Calibration managers who are not only able to provide the auditor with a thick stack of certificates, but have also understood why they chose specific instruments, calibration intervals and calibration methods, will be well-prepared for the next audit. They can thus avoid embarrassing scenes like this: The auditor asks a question about the calibration of a specific instrument, after which the calibration manager begins to feverishly look for the corresponding certificate in the hope of finding the answer. However, those who have pursued these tasks with a high level of expertise in the field of measurement technology and metrology and taken the aforementioned recommendations to heart, will not have to hesitate to provide the auditor a competent answer.

Deviation management

Deviation management means triggering a response in cases where calibration indicates that the measurements are out of tolerance or that significant drift is occurring. At a minimum, the affected instrument needs to be readjusted and recalibrated. Under

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FIGURE 4. A standard operating procedure (SOP) for calibration can specify the need for cleanroom conditions

certain circumstances, an impact analysis must be carried out to examine the quality deviations of the product or the environmental requirements. This task is too often neglected. As per experience, we observe that almost only the pharmaceutical industry addresses these issues properly.

Performing calibrations

Performing calibration is not a trivial task (Figure 4). One path to professionalizing calibration management, and the calibration process itself, can lie in enlisting the support of a calibration service provider. This can be a reasonable approach, especially if the metrology competence is not available in house. The ideal situation is when the company has a specially trained, experienced calibration manager, but it is by no means the standard in industries such as the chemical industry.

Considering the complexity of calibration management and the calibration process itself, many process owners choose to go with an external calibration service provider. Service providers can do more than carry out the calibration, however. They can support the calibration management process by becoming involved in the development of the SOPs as an example (Figure 4). Or they can provide essential help with the definition of proper calibration intervals. Providers of the relevant services can become an important partner. Acting as a trusted advisor, they provide measurement technology expertise that operators frequently lack. They can translate the requirements of the process, which only the operator is fully aware of, into the requirements of the measurement technology and the calibration process.

Benefits of accreditation

When selecting a service provider, it is essential to keep one thing in mind: the calibration technician will have an influence not only on the calibration of the instrumentation, but at the end of the day on the production process itself. Only the right partner will carry out this task in a responsible manner. While it may sound trivial, the most important characteristic properties of a service provider in this field are expertise and proficiency. Those who want to be sure that the calibration service provider knows what they are doing should pay attention to the accreditation, in line with ISO/IEC 17025, which is furnished by third-party organizations such as DAkkS (Germany), SCS (Switzer-

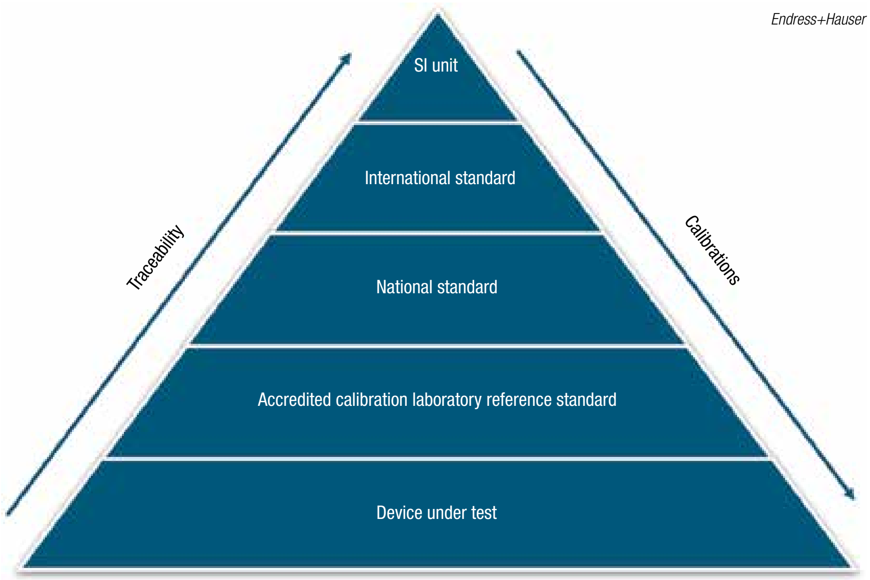

FIGURE 5. Calibration of reference instruments must be carried out with traceability in mind

land), A2LA and NVLAP (U.S.) or CNAS (China). This is not to be confused with ISO 9001 certification, which merely verifies the existence of a quality management system.

ISO/IEC 17025 accreditation is always related to specific measurement parameters, such as the calibration of pressure, flow and temperature instrumentation. It also refers to certain measuring ranges and calibration procedures and shows the suitability up to a smallest measurable uncertainty. What is important is that it verifies the necessary traceability, as well as the expertise of the service provider. During an ISO 17025 audit, one of the auditors examines the quality management system (QMS). Another technical specialist assesses the professional skills of the employees responsible for performing the calibrations. The accreditation process is extraordinarily precise, and ultimately conveys trust in the expertise of the service provider's employees. If a service provider is unable to provide the relevant accreditation, it becomes the responsibility of the organization to perform their own audit to ensure that the service provider's employees do possess the necessary expertise and follow best practices for calibration in line with ISO 17025.

The calibration service provider must be focused on the technical conditions and the plant's in-

dividual requirements. Apart from providing traceable calibration for the installed base, the calibration partner also supplies precise and comprehensive calibration certificates.

Traceability in accordance with international standards is a requirement from ISO 9001, applicable in the chemical industry. This is set out in section 7.1.5 (monitoring and measuring resources) of the standard. Calibration of the reference instruments must be carried out with traceability in mind (Figure 5). If the service partner is ISO 17025 accredited, the traceability of the calibration is guaranteed. Without accreditation however, the calibration partner has to separately demonstrate proof of traceability. That means first and foremost being able to provide the calibration certificates for the reference instruments used. In addition, not only the reference device must be traceable, but also comprise documentation of measurement uncertainty, procedure, technical competence, metrological traceability to the SI (*Système international* or international standard) units, and calibration intervals (see ILAC P-10:2002).

Time-saving methods

Calibration requires some amount of time. Calibration runs that can be arranged as part of regular maintenance works or scheduled downtimes will not affect manufacturing, but experience shows that this is a desired, but seldom achieved, scenario. This is precisely the reason why calibration should always be performed in a time-optimized manner. On-site calibration (Figure 6), for example, reduces the coordination effort as there is no need to remove and send the instrument to a calibration facility. Of course, traceability must be given even under these conditions. Even necessary adjustments or repairs of a device may under certain circumstances be carried out on site.

Some instrument types can also be calibrated in line. In this case, the instrument remains mounted and installed in its working position. The difficulty in this scenario lies in installing a reference meter in the process line, up- or downstream of the instrument to be calibrated, such as a flowmeter. This again will usually interrupt production, simply because lines have to be opened to install the reference instrument. In addition, the flowmeter of our example is usually calibrated with water, which might require rinsing of the original media first.

Another time-saving method is the multiple calibration of instruments such as thermometers, which involves the use of an oil bath. Less common are self-calibrating thermometers that ensure long-term measurement consistency by means of a highly precise and permanently stable internal fixed-point reference. This requires neither instrument removal nor interruption of the process. This type of calibration is particularly advantageous in hygienic and aseptic applications.

Unique situations can arise with special types of

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FIGURE 6. On-site density calibration can save time by eliminating the need for sending an instrument to a calibration facility

analysis instruments, like pH sensors, that operate with "smart" technologies. The sensor can be precalibrated under laboratory conditions using traceable buffer solutions. The existing sensor is then swapped out for a newly calibrated sensor, which saves time as well.

Toward integrated intelligence

While integrated systems that increase measurement reliability are the exception rather than the rule, many manufacturers are actively working to increase the metrological quality of their instruments. The goal is to be able to determine the quality of a measurement value not only at the time of calibration, but at any time while the instrument is being used. In this respect, periodic calibration is merely an aid in determining the metrological performance of an instrument. There are already self-diagnostic alternatives that verify measurement instrument performance at any time without interrupting the process, supply valuable data that make it possible to carry out predictive maintenance, and even optimize the production process. By allowing insights into the current state of the measurement instrument, self-diagnostics can also help to precisely plan, or even potentially extend, the calibration cycles. It is also advisable to combine these types of diagnostic technologies with the opportunities that artificial intelligence and the industrial internet of things (IIoT) offer. This increases reliability, which can then be used to predict when a calibration is required or potential instrument damage.

Putting it all together

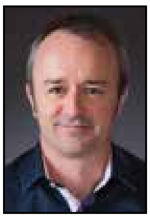
Professional calibration means a lot more than satisfying the auditor with a stack of certificates. Apart from ensuring the conformity of the process and the quality of the product, professional calibration first and foremost improves the quality of the process. This leads to safe processes that run with a high degree of efficiency, plus proper reporting that can be used for pinpoint optimization.

The basis for professional calibration is to bring together the competencies for the production process, quality assurance, process safety and metrology to do the necessary calibration work — nothing more, nothing less. The question of appropriate calibration intervals should not be paramount. Instead, the focus should be on how to ensure the consistent process stability and the constant availability of the necessary measured values in the appropriate quality. If you optimize your existing calibration intervals keeping the above in mind it may lead to significantly increased calibration intervals for certain instruments and reduced intervals for others. But even if it leads to more frequent calibration, you will ultimately achieve an optimum with the least possible use of resources — which basically means that your installed base will gain a higher degree of reliability.

Furthermore, those who understand how to utilize the opportunities that (self) diagnostics and digitalization offer with regard to quality and calibration management are in a better position to design their production systems for the future. The extensive basis of data that the intelligent measurement instruments provide, combined with artificial intelligence and IIoT, helps to provide operators with support over the long-term. This will eventually not only drive down costs, but also allow for proactive management of deviations and countermeasures as well as optimizing the instrumentation, thus making significant progress toward operational excellence. ■

Edited by Gerald Ondrey

Authors



Dimitri Vaissiere works as an expert data scientist in the Service Innovation division at Endress+Hauser (Deutschland) AG+Co. KG (Colmarer Strasse 6, 79576 Weil am Rhein, Germany; Phone: +49-7621-975-01; Fax: +49-7621-975-555; Email: dimitri.vaissiere@endress.com). He holds a doctorate in engineering sciences from the University of Strasbourrg, France. He has been working for the company since 2010 and spends his free time with boxing or with his children hiking.

Pia Höfflin is a service product developer at Endress+Hauser (Deutschland) AG+Co. KG (Colmarer Strasse 6, 79576 Weil am Rhein, Germany; Phone: +49-7621-975-01; Fax: +49-7621-975-555; Email: pia.hoefflin@endress.com). She joined the company in 2014. Currently, she is responsible for developing maintenance optimization and calibration optimization services. Höfflin holds an engineering degree from DHBW Lörrach, Germany. She enjoys travelling through Europe and exploring new places.

Technologies for Controlling H_2S

There are many industrial technologies for removing H_2S from process gas, and each brings with it different benefits with regard to costs, efficiency and equipment layout

Christopher Ristevski and Rosanna Kronfli
Macrotek Inc.

Hydrogen sulfide (H_2S) is a toxic and corrosive gas that occurs naturally, but can also be produced through many industrial processes. In addition, H_2S has an odor threshold of 0.01–0.15 parts per million (ppm), according to the Occupational Safety and Health Administration (OSHA; Washington, D.C.; www.osha.gov). Due to the very low odor threshold, in countries where nuisance odor is regulated, H_2S removal from process gas or off-gas is required. Since H_2S is produced through anaerobic digestion, it is prevalent where organic matter and sulfates are present. As a result, pipeline gas specifications exist to ensure gas quality. Furthermore, when natural gas, synthesis gas (syngas) or biogas is used in turbines or engines for power generation, H_2S concentrations cannot exceed the engine manufacturer's specifications, due to corrosion concerns. During combustion, H_2S is oxidized to sulfur dioxide — a highly regulated air pollutant — which necessitates its removal before combustion. It is clear that H_2S removal is important for the environment, industrial equipment integrity and human health.

H_2S can be removed from process gas through various technologies, depending on the application, process conditions and removal requirements. This article describes selected proven technologies for controlling H_2S in small- to medium-sized applications, including natural gas production, landfill gas recovery, waste-to-energy systems, biogas production and wastewater treatment plants.

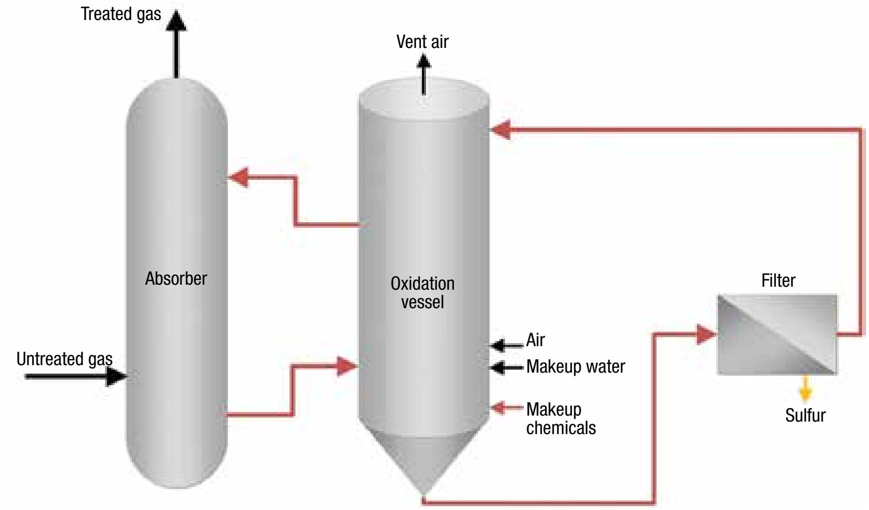


FIGURE 1. In a typical liquid redox system, a catalyst (typically chelated iron) converts H_2S gas into sulfur in an aqueous system

Liquid redox

Liquid redox refers to technologies that absorb H_2S and oxidize it to sulfur in an aqueous system using a catalyst (most commonly chelated iron). The chelated iron converts H_2S gas into solid sulfur, as shown in the below chemical reactions:

$$H_2S + 2Fe^{3+} \rightarrow S + 2Fe^{2+} + 2H^+ \quad \text{(Reduction of iron)}$$

$$2Fe^{2+} + \tfrac{1}{2}O_2 + H_2O \rightarrow 2Fe^{3+} + 2OH^- \quad \text{(Oxidation of iron)}$$

$$H_2S + O_2 \rightarrow S + H_2O \quad \text{(Overall reaction)}$$

As can be seen, only oxygen is consumed in the reaction. The chelating reagent is not consumed, because it is continually regenerated by forced oxidation using air. Although the reagent is not consumed in the process, a small amount of loss is typically experienced, mainly due to chelate degradation over time. Since solid sulfur is produced, filtration can be used to remove the sulfur and recycle the reagent back into the process. This eliminates or significantly reduces the production of wastewater and the associated costs. The sulfur that is produced can also potentially be sold as a product.

The main vessels in a liquid redox system include an absorber and an oxidation vessel (Figure 1). In the absorber, H_2S is absorbed into the liquid and converted into sulfur. The spent recirculating liquid is sent to the oxidation vessel where contact with air regenerates the solution into its active form. The regenerated solution is re-circulated back to the absorber to complete another reaction cycle. Some systems use a settling tank to concentrate the sulfur before sending it to a filtration system for removal from the process. Typically, 316L stainless steel is used as the material of construction for the process equipment.

Overall, liquid redox systems require minimal water and chemical addition and produce minimal waste. This results in very low operating costs compared to alternative technologies. The systems are also capable of handling

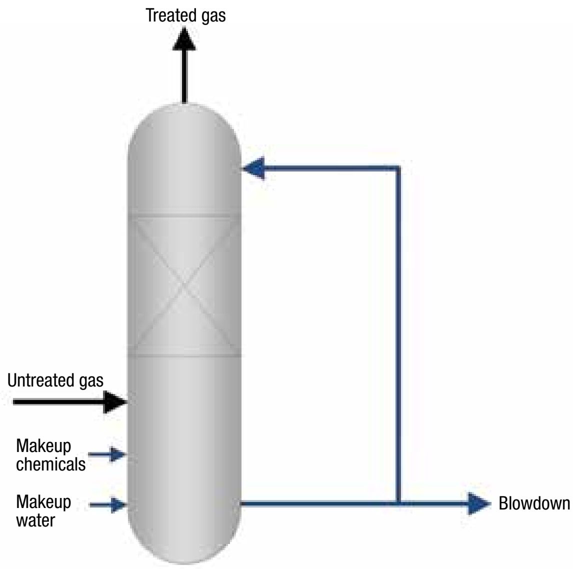


FIGURE 2. A chemical oxidation system neutralizes H_2S gas using a base, typically sodium hydroxide

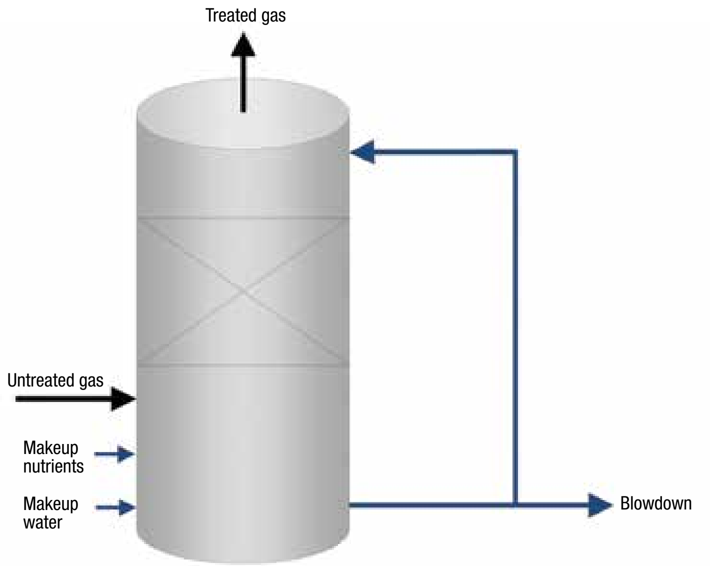


FIGURE 3. Biotrickling processes use autotrophic microbes to consume and transform H_2S

large fluctuations in inlet composition and gas flow while maintaining high H_2S removal efficiencies of greater than 99.9%. The systems are, however, higher in capital costs due to the increased control sophistication that is required. Although most liquid redox systems have very similar overall chemistry, different suppliers use different chelating agents to keep the iron in solution. Some of the chelating agents, such as nitrilotriacetic acid (NTA), are hazardous. Recent advancements in this technology have helped drive down the operating costs through the development of innovative chemical reagents that reduce chemical consumption rates. Similarly, the equipment and installation costs are being reduced due to modularization and skid-packaged offerings.

Chemical oxidation scrubber

In a chemical oxidation scrubber, a base, typically sodium hydroxide (NaOH), is used to neutralize H_2S gas after absorption into the scrubbing liquid. The absorbed H_2S is then oxidized using a chemical oxidizing agent, typically hydrogen peroxide (H_2O_2) or sodium hypochlorite (NaOCl), to form soluble sodium sulfate (Na_2SO_4), as shown in the overall equation below. Na_2SO_4 is removed from the system through a blowdown stream. This sulfate-containing wastewater (blowdown) must be treated or sent for disposal.

$$H_2S + 2NaOH + 4H_2O_2 \rightarrow Na_2SO_4 + 2H_2O$$

(Overall reaction with NaOH and H_2O_2)

Packed-bed scrubbers are the most common process equipment used for chemical oxidation (Figure 2). Vertical countercurrent packed-bed scrubbers are generally preferred due to their high efficiency. Compared to a spray tower, tower packing provides additional mass transfer and therefore smaller equipment size and pumping costs for the same performance.

In the vertical countercurrent design, gas flows upward while scrubbing liquid flows down through spray nozzles or a liquid distributor above the random packing section. The absorption of gases occurs in the packing section. A mist eliminator inside the vessel removes entrained liquids from the gas before exiting the scrubber. A regulated amount of the reagents is added to the re-circulating liquid to maintain setpoint pH and oxidation-reduction potential (ORP) levels. Fiber-reinforced plastic (FRP) is typically the material of choice for the process vessels, particularly if sodium hypochlorite is used as the oxidizing agent.

One of the disadvantages of chemical oxidation is that caustic is not selective to H_2S in the presence of other contaminants, such as carbon dioxide (CO_2). Not only does CO_2 increase chemical consumption, but the reaction products can cause scaling in the packing. Care must be taken during the equipment design and selection of process setpoints to ensure CO_2 interference is minimized.

Chemical oxidation scrubbers are compact and low in cost. They are also capable of handling large fluctuations in inlet composition and gas flow while maintaining high H_2S removal efficiencies of greater than 99.9%. The chemicals that are used are commodity chemicals, and therefore, availability is rarely a concern. The rate of chemical consumption can be high relative to the amount of H_2S that is treated. For example, for every 1 mole of H_2S, 2 moles of NaOH and 4 moles of H_2O_2 are required, as shown in the overall reaction. Furthermore, handling the sulfate-containing wastewater stream adds significantly to the operating cost of the scrubber.

Biological processes

There are several types of H_2S removal technologies that use biological or biochemical processes. This article focuses on biotrickling filters, which use autotrophic microbes to consume H_2S and convert it into sulfuric acid. Biotrickling filters consist of a vessel with a packed or porous media section (Figure 3). The media provides a large surface area for the microbes to grow on. Makeup water is required to maintain the pH, and a

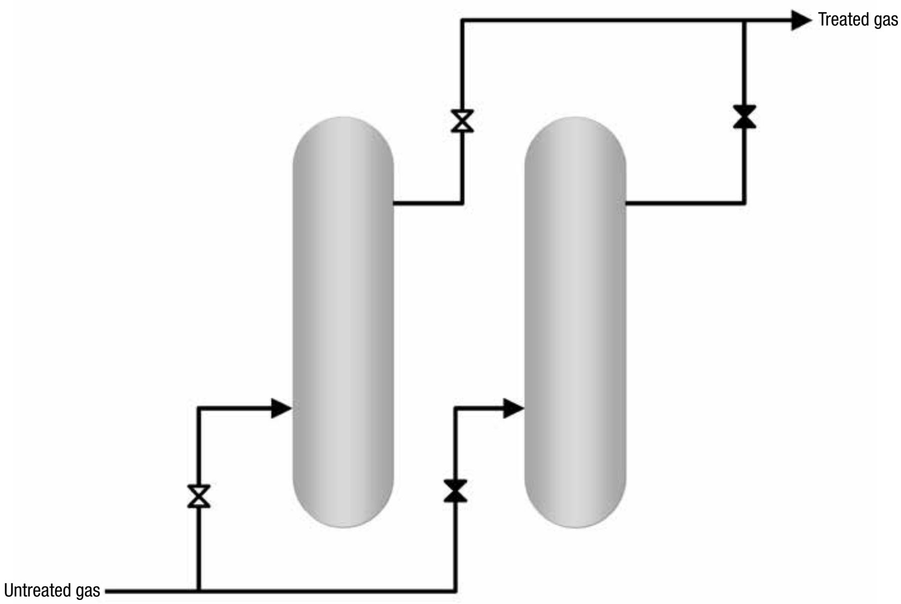


FIGURE 4. A scavenger system involves the injection of a liquid or solid chemical to irreversibly react with H_2S

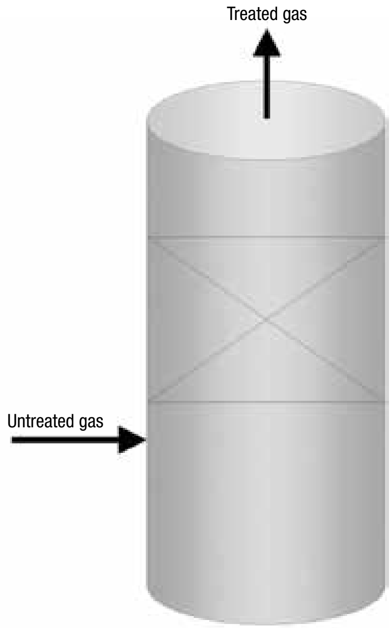


FIGURE 5. Adsorption of H_2S using a fixed-bed activated-carbon process is appropriate when a very low outlet concentration of H_2S is required

blowdown stream of dilute acid is removed from the system. NPK (nitrogen, phosphorus and potassium) fertilizers or other mixtures (such as unchlorinated raw water) are used to provide the nutrients that are required by the microbes. Nutrient addition can be done manually or can be mixed at a fixed ratio with the makeup water. When a biotrickling filter is installed, it may take several days for the biofilm to develop on the media, and during this phase, the removal efficiency

TABLE 1. SELECTED PROCESS FEATURES OF H_2S REMOVAL METHODS

Process Features		Liquid redox	Chemical oxidation	Biotrickling filters	Scavengers	Carbon bed
Typical application range, kg/d	Low H_2S Loading (<5)		✓	✓	✓	✓
	Medium H_2S Loading (5–50)	✓		✓		
	High H_2S Loading (>50)	✓				
Minimal waste generation		✓		✓		
Regenerative reagent		✓				
Non-hazardous reagent		Varies		✓	Varies	✓
Non-hazardous byproduct		✓	✓		Varies	
Usable byproduct generation		✓				
Low freshwater requirement		✓		✓	✓	✓
High turndown		✓	✓		✓	✓
Ability to handle process variability		✓	✓		✓	✓
Low operating costs		✓		✓		
Low capital costs			✓		✓	✓
Low complexity					✓	✓

will be low. Concrete structures are often used for large gas-flow systems, while FRP can be used for smaller units.

The bacteria are sensitive to humidity, temperature and fluctuating H_2S inlet loading. Recirculating liquid supplied by a pump, or once-through water, is required to keep the packing or media wet. If the media is allowed to dry, the microbes will become inactive. Furthermore, biotrickling filters require long residence times, resulting in large vessels. Little operator intervention or maintenance is required other than daily checks of pH and media pressure drop.

Scavengers

Scavengers can either be liquid- or solid-phase chemicals that react with H_2S. Typically, these reactions are irreversible (non-regenerative), resulting in the need to periodically replace and dispose of the scavenger. Depending on the type of scavenger used, byproducts can be hazardous, making disposal costly. The most common liquid scavengers are triazines, which react with H_2S to form water-soluble sulfur compounds. Common solid scavengers include metal oxides, particularly iron, which react with H_2S to form sulfides. Regenerative liquid and solid scavengers (such as amines, molecular sieves and so on) are not discussed here, as they do not eliminate the H_2S. Instead, a waste gas with a high H_2S concentration is produced during the scavenger-regeneration process, which must be treated or sent for disposal.

Like other H_2S-removal technologies, most scavengers require dedicated process equipment (Figure 4). In some cases, direct inline injection is possible with liquid scavengers. The process equipment consists of vertical towers where gas flows up through the liquid or media. For liquid systems, the gas is usually bubbled through a liquid-filled absorber vessel. For solid systems, the gas flows up or down through a fixed bed.

Furthermore, since the scavenger reagent is consumed by the reaction, two vessels in parallel are often installed such that one vessel can be taken offline in order to replace the scavenger. Scavenger systems use simple process equipment and require only basic controls, resulting in a relatively low capital cost. On the other hand, operating costs can be high due to high chemical consumption and treatment of waste streams. Carbon steel is often used as the material of construction for the process equipment.

The advantage of scavengers over other discussed technologies is their selectivity of H_2S over CO_2. However, the disadvantage is that most scavengers can be sensitive to high temperature and require gas with high humidity.

Fixed-bed activated carbon

Adsorption of H_2S is a physical process where H_2S is captured onto the surface of activated carbon. The media has a large specific surface area due to its inner pore structure, which provides a large adsorptive capacity. Carbon beds are particularly suitable when very low outlet concentrations are required. In addition to the physical process, some activated carbons have catalytic properties that oxidize H_2S into water-soluble sulfur compounds. This allows the carbon to be washed for regeneration until spent, at which point, disposal is required.

Since the process does not occur in the liquid phase, liquid recirculation, chemical addition and the associated controls are not required, resulting in relatively simple process equipment and operation. A carbon-bed vessel is typically sized based on the carbon usage rate and superficial gas velocity. The vessel configuration is typically vertical, with gas flowing up through the fixed-carbon bed (Figure 5). When the activated carbon is spent, the media must be replaced. Some plants will install two units in parallel for continuous operation. Since the superficial gas velocity is very low through carbon beds (higher superficial gas velocities result in excessive pressure drops), large-diameter vessels are required even for low flowrates. Therefore, carbon beds are often better suited for polishing applications or for low H_2S loadings, and as such, some plants do not include an installed spare vessel, but instead elect to exceed their H_2S emissions during the time that they are replacing the carbon.

Activated carbon is sensitive to humidity and temperature, among other parameters, such as particulate matter loading. Water blocks the adsorption sites and, as a result, decreases its effectiveness. Similarly, increased temperature has negative effects on capacity. These systems also work best under positive pressure, because increasing pressure increases the amount of H_2S ad-

sorbed. The most common materials of construction for carbon beds include coated carbon steel, FRP and other plastics.

Technology selection

Selection of the appropriate H_2S-removal technology is mainly governed by cost and technical suitability. Table 1 provides a summary of the process features offered by each technology. Generally, for high H_2S loadings, regenerative or biological technologies are more economically feasible than non-regenerative types due to their lower operating cost per unit of H_2S removed. This is mainly because of the lower consumption of chemicals or media. Furthermore, non-regenerative technologies are less complex than regenerative systems and the capital cost is consequently lower. Generally, regenerative systems result in short payback periods for applications where the inlet H_2S loading is more than 50 kg/d. However, the exact breakeven point will vary for each application. For reference, a gas flow of 1,000 std. ft^3/min containing 850 ppm of H_2S corresponds to a loading of 50 kg/d of H_2S.

Most technologies are suitable for applications where high process variability or high turndowns are required, with the exception of biotrickling filters, which require a constant amount of H_2S in order to maintain the biofilm. This makes biotrickling filters difficult to use in applications with frequent shutdowns or variable inlet conditions unless periodic H_2S excursions are acceptable. This is why biotrickling filters excel in wastewater treatment plants, but are rarely utilized in other industrial processes.

The choice between the three non-regenerative technologies discussed here often comes down to plant preference and ability to manage the chemical inputs and waste streams. Chemical oxidation scrubbers have the smallest footprint and are continuous processes, while scavenger units and activated carbon beds are larger and must be shut down to replenish the spent media or chemical unless a standby unit is installed. Solid media is also less desirable to handle on a regular basis. Therefore, solid scavengers and carbon beds are typically used for low-H_2S-loading applications or as a polishing stage to avoid frequent change-out.

In the past, liquid redox systems were best suited for applications with very high H_2S loadings, particularly for natural gas and landfill gas processing. The high capital cost of a liquid redox system resulted in a technology that was not economically feasible for lower H_2S loadings. As a result, scavenger systems and chemical oxidation systems became the technology of choice, even though the operating costs are greater. However, emerging technology advancements have resulted in lower capital costs. This has allowed liquid redox systems to become feasible and attractive alternatives in small- to medium-sized application ranges. ■

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Authors

Christopher Ristevski currently leads the Process Engineering team at Macrotek Inc. (421 Bentley Street, Unit 1, Markham, Ontario, L3R 9T2; Email: cristevski@macrotek.com). With 10 years of experience, he has a wide range of expertise in air-pollution-control systems, including system integration, process design, process modeling and equipment and controls selection. He has also led the development of innovative new air-pollution-control technologies, such as the SULFCAT process, and is now responsible for the implementation of these systems worldwide. He holds a degree in chemical engineering from the University of Toronto.

Rosanna Kronfli is an applications engineer at Macrotek Inc. (Same address as above; Email: rkronfli@macrotek.com). She joined Macrotek in 2015 and has a wide range of experience in air-pollution-control equipment and process design. She holds bachelor of applied science and master of applied science degrees in chemical engineering, both from the University of Toronto, and is a licensed Professional Engineer with Professional Engineers Ontario.

Improving Mathematical Model Development and Implementation

This article provides practical guidance for engineers and highlights the importance of combining mathematical skills, domain expertise and proper communications

Christophe Grosjean, Anita M. Rea and Patrick M. Piccione*
Syngenta

The role of mathematical models in chemical engineering keeps increasing, to the point that some engineers become specialized "modelers." To combine mathematical skills, domain expertise, and usage conditions more effectively, all forms of communication and the exchange of information between modelers and their customers must be given proper attention. Some guidelines and recommendations are discussed below.

What are models?

Models are representations of reality — conceptual, mathematical or a combination thereof. They are flexible, simplified versions of complex real systems for which there is a desire to better understand and predict how the systems work or what types of outputs they can produce.

Models are ubiquitous in scientific endeavors, and, over the years, process modeling of physico-chemical systems has become a valuable tool for the engineer. Mathematical models built from first principles, or using pre-existing modules, have the ability to save time and material, and also improve quality, efficiency and safety during process and product design, troubleshooting or optimization studies. The ability to work with models that also interact iteratively with experimental capabilities and efforts can help to optimize overall resources.

The required complexity and accuracy of a model is generally governed by its desired purpose, although a flexible design allows users to address simple queries upfront with the option of extending the efforts to more complex interrogation later.

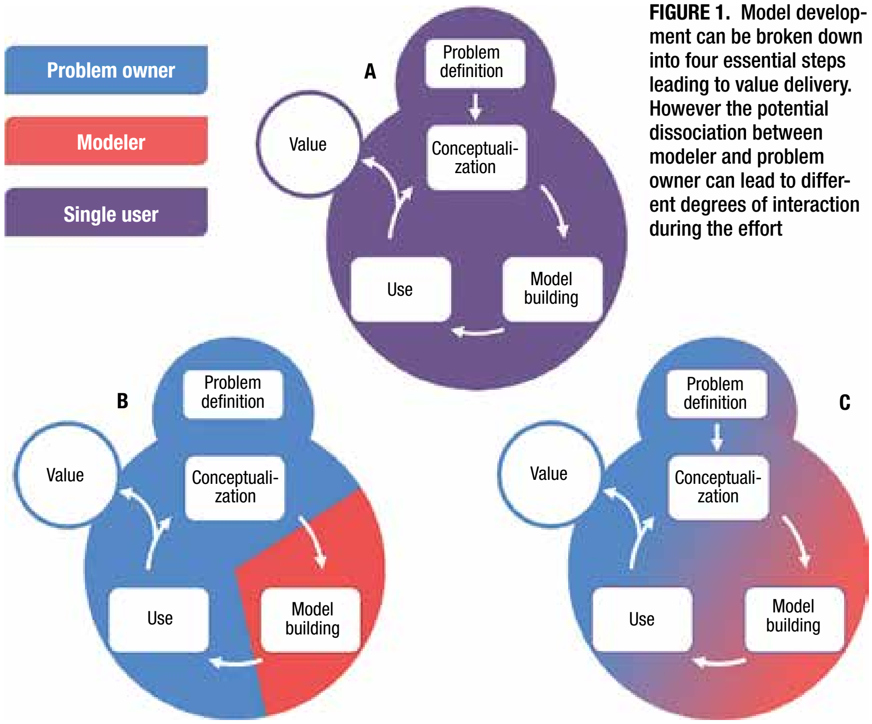

FIGURE 1. Model development can be broken down into four essential steps leading to value delivery. However the potential dissociation between modeler and problem owner can lead to different degrees of interaction during the effort

Model development

As shown in Figure 1, the modeling process can be broken down into several steps that are essential for successful value delivery. All steps need direct involvement from both the problem owner and the modeler:

A. Defining the questions to be answered
B. Conceptualizing the process into (the correct) phenomena
C. Model building, that is, translating the phenomena and its parameters to mathematical expressions and validating assumptions and predictions
D. Model use

As an aspirational goal, most chemical engineers should be able to perform an element of model design and could theoretically complete the cycle shown in Figure 1A themselves. However, by necessity, mathematical models are often developed by specialists. Such designated "modelers" apply mathematics to translate the system under study, using core engineering principles, to its underlying equations. The majority of the "problem owners," on the other hand, help to relate the model to the process at hand and the practical operating parameters they know will impact the model output.

These complementary, yet seemingly opposed approaches stem from a healthy differentiation of scope, remit and job objectives. Ideally clear interactions are required to ensure that the purpose (and hence

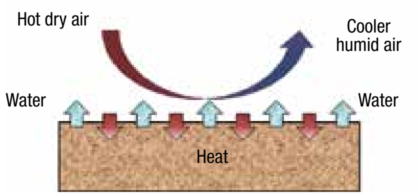

FIGURE 2. Evaporative drying is a classic engineering example of concomitant heat and mass transfer

* Patrick M. Piccione is now with F. Hoffman-La Roche

resulting value proposition) of the model is not lost on the end owner, and the model itself is well-designed and fit for purpose (that is, Figure 1C is a preferable operating model over Figure 1B).

Echoing a recent call for improving communications throughout the chemical engineering community, this article draws attention to the crucial role communication has on model development and its many uses [*1*].

Conceptualization

Assuming the underlying chemical engineering problem or challenge has been carefully defined by its owner, a first step in the development cycle is to identify the key phenomena that will lead to using the appropriate equations to describe the process. In the case of a model that relates to evaporative drying, for example, the main chemical engineering phenomena considered would be heat and mass transfer (Figure 2).

The conceptualization step, and the next (model building), will ensure that a sharable support (document) for knowledge retention is created by the very process of model development.

Model building

Following conceptualization, the identified key phenomena can be translated in different mathematical ways. For instance, the transport of water out of solid materials during drying can be described using either diffusion or capillary movement (or both) [Equations (1) and (2)].

Drying and diffusion theory:

$$\frac{dw}{dt} = -\frac{2D_L}{l} \times e^{-\left(\frac{D_L t\pi^2}{4l^2}\right)} \times \left(w - w_{eq}\right) \tag{1}$$

Drying time using the capillary theory:

$$t_{f,cap} = \frac{\rho_s l h_{fg} \times \left(w_0 - w_{eq}\right)}{h \times (T_{abs} - T_S')} \times ln\frac{\left(w_0 - w_{eq}\right)}{\left(w - w_{eq}\right)} \tag{2}$$

Where:
w = Total moisture, kg
t = Time, s
D_L = Diffusion coefficient (liquid phase), m^2/s
l = Thickness, m
w_0 = Initial moisture, kg
w_{eq} = Equilibrium moisture, kg
$t_{f,cap}$ = Drying time based on the capillary theory, s
ϱ_s = Density of the dry solid, kg/m^3
h_{fg} = Latent heat of vaporization, J/kg
h = Heat transfer coefficient, W/m^2K
T_{abs} = Absolute air temperature, K
T'_S = Evaporative surface temperature, K

The most appropriate description will depend largely on the nature of the material and the amount of water to be removed. The decision will be supported and validated by either purposefully designed experiments or historical data.

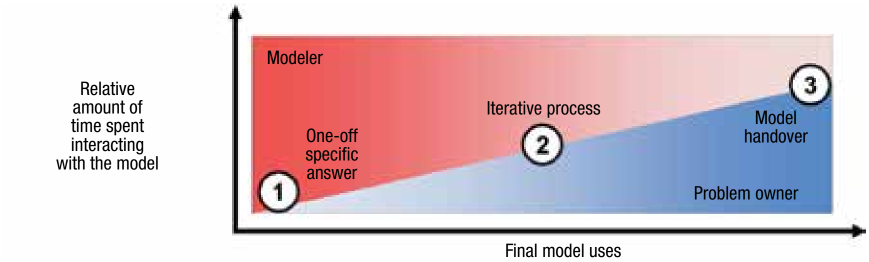

FIGURE 3. The end use of the model will dictate the relative amount of time both the modeler and the problem owner will spend with the model

Critically though, the appropriate description depends on the end use of the model.

Model use

The relative levels of interaction of the problem owner and the specialist modeler with the model is highly dependent on its final use and anticipated results (Figure 3). Recognizing this will ensure that maximum utility can be gained.

Figure 3 distinguishes among three likely outputs of modeling work, on a continuum of usage conditions. First is a case where the desired output is a single answer to a specific question (Case 1), such as an estimation of a physical property for a chemical process. For this case, interactions between the model and the owner may be very limited, with the modeler generating the information. In order to ensure successful value delivery, the two parties must jointly develop the following:

- A clear definition of the problem and objectives in the wider context of the full project
- A statement of the model's limitations with respect to applicability and prediction uncertainty

The latter is common to all modeling work but is especially relevant to this example, as the owner has no plan to return to the modeler for additional work. Should he or she do so, the relationship between the modeler and the owner moves toward a more iterative process scenario (Case 2).

Such a situation requires significantly more effort on the communication front. Let us consider an example where the problem owner requires modeling of chemical yields for a process at different conditions (Figure 4).

A mechanistic model can be built, based upon the correct identification of the governing phenomena within a specific process envelope. Such a model is based on a causal, first-principles description of these phenomena. The owner can then apply the model to predict outputs under different conditions within the pre-defined model operating range only. The inherent challenge here is to have the problem owner provide the right input to the modeler, since model revisions outside the original envelope are out of scope. This requires both an understanding of the limitations of the model, and an appreciation of the fact that poor input data will generate poor results.

The final case is one in which the aim of the modeling exercise is to create a flexible tool that will be delivered to the owner for recurring use (Figure 3, Case 3). This type of activity is perhaps the most challenging, because it presents the greatest risk of misunderstanding between modeler, owner and even the model.

Consider the example of a plant process unit where the owner is the site manager. The site manager wants to improve scheduling around that unit operation by simulating the impact of a wide range of operating parameters. In this instance, there is a large potential for one of two possible pitfalls:

- Incorrect model development (for instance, over-simplification or over-complication) due to insufficient understanding of the process and its drivers by the specialist modeler
- Incorrect use, and therefore value delivery, due to incomplete understanding of areas of applicability

Useful systematic practices that can help to circumvent these issues include project kick-offs and peer reviews, together with formal technology-transfer packages, and a follow-up on tool use (in terms of not just the science but the implementation support that is needed).

Delineating usage conditions

The discussion above on model uses is necessarily quite abstract, but highlights the need to be clear on condition of use. The use of a metaphor can be useful in such a situation. Figure 5 uses an analogy based on medicine to facilitate communication between the modeler and the end user.

Here the model is compared to a diagnostic tool. In a first instance, the objectives are defined based on context — that is, the patient is sick and there is a need to determine what has caused the sickness. This leads to ongoing discussions that define the requirements, and the later develop-

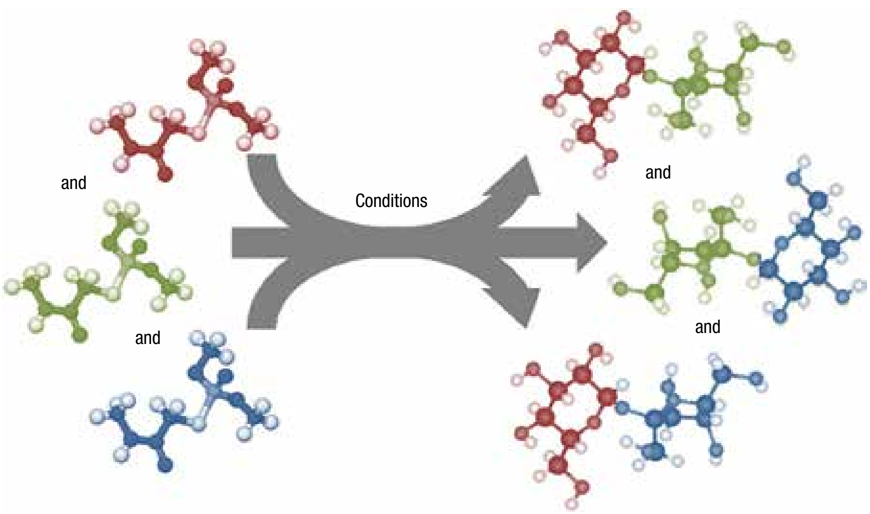

FIGURE 4. The ability of a model to predict the outcome of a specific reaction for a variety of reactants is largely dependent on the input quality of the problem owner, who needs to foresee applications beyond its original request from the onset

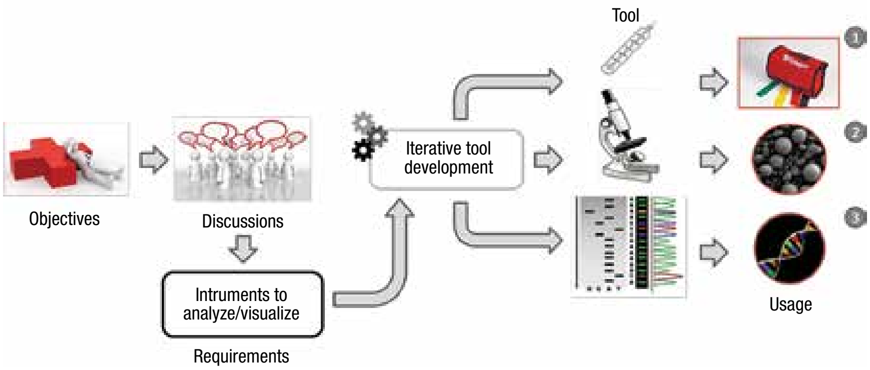

FIGURE 5. For a given set of symptoms, several diagnostic tools are conceivable. However, the end use alone can direct the development of the tool

ment of a diagnostic tool.

However, it is the eventual use of the tool that will determine its design. The expected use could be a simple one-off answer to support triage (Case 1 in Figures 3 and 5), in which case a diagnostic based on temperature (for instance, using a thermometer) might be sufficient.

In a more extreme case, if a new pathogen is suspected, DNA sequencing could be envisaged to determine the cause of the sickness (Case 3). In this instance, the diagnostic tool can be used to both gain insight and make decisions.

An intermediate case is that of fast preliminary assessments, for which a new type of field microscope might be sufficient (Case 2). The medical analogy presented here provides a simple illustration of tool differentiation (in this case, model development) based on final usage to ensure appropriate design.

All modeling tools are unique and their usages vary from one project to the next. Nonetheless, only with effective, targeted communication between the user and the modeler can value be delivered. Aspirationally, with modern software, modeling will become a more accessible activity so there will not be a distinction between modelers and problem owners — rather, all users will be able to do some model development. In the meantime, you must think carefully about how to foster the most effective communication among all parties the next time you integrate modeling into your workflow. ■

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Authors

Christophe Grosjean is the technology and innovation lead for formulation engineering at Syngenta AG (Breitenloh 5, 4333 Münchwilen, Switzerland. Phone: +41 62 868 5686; Email: christophe.grosjean@syngenta.com). He holds a chemical engineering degree from IUT Le Montet (Nancy, France), and a Ph.D. in physical organic chemistry from Durham University. After further postdoctoral studies at Durham, he joined LyraChem Ltd, a start-up company established from a collaboration between Newcastle and Durham universities' chemical engineering and chemistry departments, respectively. During that time, he was responsible for the process modeing, experimental studies, and reporting of business projects. Grosjean joined Syngenta in 2013, and has worked on a number of process modeling projects, supporting the seeds and active ingredients parts of the business.

Anita Rea is process studies manager at Syngenta's International Research Center (Bracknell, Berkshire RG42 6EY, U.K. Phone: +44 1344 41 4102; Email: anita.rea@syngenta.com). She holds a Ph.D. in Biophysics from the University of Notthingham, and was a postdoctoral researcher at the MRC Laboratory of Molecular Biology (LMB) in Cambridge, U.K. In her current role, Rea leads a cross-disciplinary department of engineers, chemists and physical scientists in the application of fundamental science to the development, manufacture and formulation of agrochemical active ingredients.

Patrick M. Piccione is the head of formulation and process sciences at F. Hoffmann-La Roche (Grenzacherstrasse 124, 4070 Basel, Switzerland. Phone: +41 61 687 7510; Email: patrick.piccione@roche.com). He spent seven years in materials development at Arkema, followed by nine years at Syngenta, leading process engineering science. At Syngenta, Piccione also led a division-wide mathematics and data-science strategy, which prominently featured models together with their development and dissemination. He holds B.S. degrees in chemistry and chemical engineering from MIT, as well as an M.S. in chemical engineering practice, and a Ph.D. in chemical engineering from the California Institute of Technology. He has co-authored more than 30 journal and proceedings articles on various topics. He is a Chartered Engineer and Fellow of the IChemE, and is currently serving on the Executive Board of the European Federation of Chemical Engineering.

The Valve World Americas Expo and Conference (www.valveworldexpo americas.com) will take place at the George R. Brown Convention Center in Houston (June 19–20, 2019). Organized by KCI World and Messe Düsseldorf North America, the 2019 edition of the bi-annual event will serve as the meeting point for the flow control industry, with a technologically in-depth conference program, product showcases on the expo floor and numerous networking opportunities. Attendees will get a broad overview of the latest technologies, components and systems in the field of industrial flow control presented by over 324 exhibitors from the U.S., Asia, Canada, Europe, India, Mexico and more.

In addition to the exhibition, the Valve World Americas event will cover a variety of valve and valve-related topics. There will be plenary presentations on a number of hot themes in the valve industry, including the future of shale gas and the outlook on the energy industry.

For attendees looking to obtain professional development hours, conference delegates will be awarded certificates of completion for participation. Certificates will be available for pick up during the event Closing Ceremony. Workshop topics include: valve technology for cryogenic applications; valve design; valve testing for emissions; materials specification & casting; supply chain; valve asset management; control valve reliability prediction; performance and validation; actuation & automation; maintenance & repair; and ESDV (emergency shut-down valve) reliability.

A sample of products being exhibited is given below.

Flange inserts for vacuum applications

This company is introducing the new Vacuum Flange Insert (VI: photo) for rough- to high-vacuum systems, systems requiring frequent cleaning or modification, roughing and foreline plumbing, research and teaching laboratory applications, and more. The VI is designed to fit between ISO/NW/KF/QF vacuum flanges designed in accordance with DIN 28403, DIN 28404, ISO 1609 and ISO 2861. It is both a centering ring and a check valve, and therefore requires no additional space in the line. Its size makes it extremely economical when compared to full-bodied check valves. The VI can also be used as a low-pressure relief valve under either positive pressure or vacuum conditions by using the desired spring setting. Stand 1218 — *Check-All Valve, Des Moines, Iowa*
www.checkall.com

These check valves are engineered to avoid slamming

This company manufactures seven different types of check valves. The portfolio includes the Dual Disc, Foot Valve, Silent Check, Swing Check, Swing-Flex, Surgebuster and Tilted Disc, which are highly engineered to provide long life and trouble-free performance to meet the valve needs of users. Engineers weigh the importance of slamming characteristics as one of the factors when selecting a check valve. All of this company's check valves are designed with non-slam characteristics, such as the seat angle of the Swing-Flex and Tilted Disc. The Surgebuster uses the addition of the Disc Accelerator to prevent slamming in the most severe applications. The versatile Foot Valve can provide positive seating action at both low and high pressure without slamming. And if you are not sure which check valve to use for your application, the company has redesigned its white paper "Design and Selection of Check Valves" to learn which valve is your best option. This white paper will help you understand basic valve principles and the functions of various types of check valves used in pumping systems. Engineering parameters associated with check-valve selection, such as flow characteristics, are discussed, along with headloss, reliability and costs. The combined characteristics of the pumps, check valve, air valve, control valve and surge equipment should be considered for successful pumping system design. With this knowledge, engineers can better select check valves and understand some pitfalls common to valve selection. Stand 534 — *Val-Matic Valve, Elmhurst, Ill.*
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Emerson Automation Solutions

These valve actuators support Ethernet/IP

This company's electric valve actuators now support the Ethernet/IP Industrial Ethernet communication standard, in addition to Profinet and Modbus TCP/IP. With bandwidths up to 100 Mbit/s, Ethernet/IP provides reliable and rapid exchange of both cyclic process data and acyclic diagnostic data from the actuators. The company recently supplied and commissioned 49 actuators with Ethernet/IP communications to the Santan Vista water treatment plant in Arizona (photo). "Integrating the actuators into the Ethernet/IP system proved to be easy and straightforward," says Lido Flores, regional sales manager in the U.S. "Many of our customers already use Ethernet/IP for their sensors and meter devices. We are happy to now also provide electric actuators that use this future-proof technology." Stand 926 — *AUMA Actuators, Inc., Canonsburg, Pa.*
www.auma.com

Manual ball valves with integrated position feedback

This company offers a technically advanced solution for ball valves for manual operation with suitable position feedback. And these are already pre-assembled, preset and tested. At first glance, there are a multitude of ball-valve and electrical position-indicator providers. However, many of these providers offer either one or the other. As a result, the individual components often have to be acquired from two different suppliers. This means that the two components must be assembled locally on the construction site before they can be placed in the plant — a process that is very time consuming. This company is reducing the effort required on site and offering manually operated ball valves with an integrated electrical position indicator. The pre-assembled valves save on the time and effort required for logistics and documentation and enable faster and simpler installation of the plant on site. For the GEMÜ 711 and GEMÜ 740 three-piece ball valves, the GEMÜ 762 one-piece compact flange ball valve (photo) and the GEMÜ 797 high-pressure ball valve, the company is offering the LSF inductive dual sensors or the LSC limit switch box. Stand 435 — *GEMÜ Valves, Atlanta, Ga.*
www.gemu.com

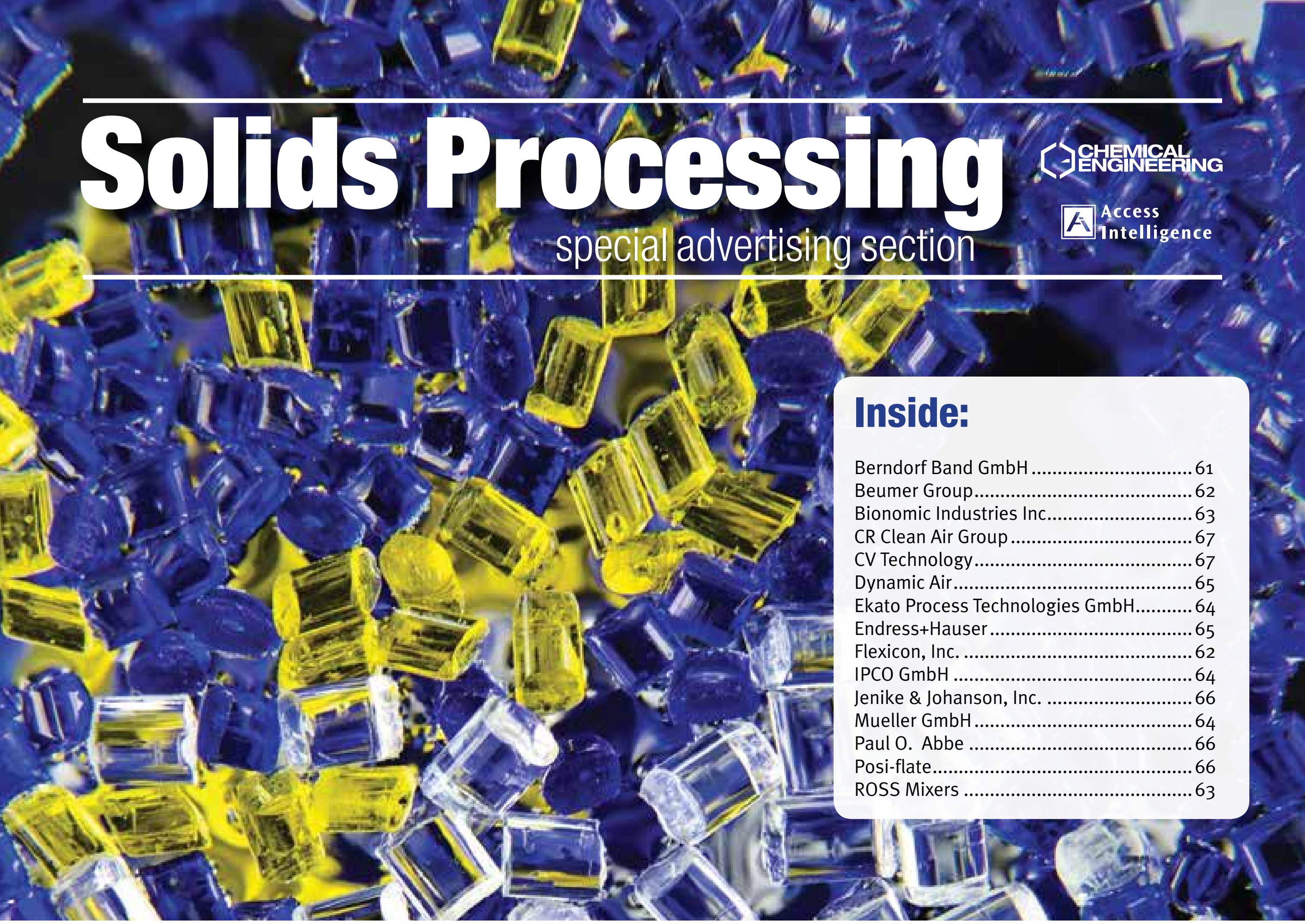
New manifold valve design for pressure transmitters

Manifolds shut off or equalize pressure at the transmitter and provide the critical mounting mechanisms required in many installations. The Rosemount R305 Integral Manifolds and Rosemount R306 In-line Manifolds (photo) have been designed to offer significant user improvements on these basic functions. The most important improvement for both manifolds is the new Pressure-Lock Valve design, which simplifies high-pressure operation, increases safety and enhances reliability. New features include: two-piece stem does not rotate in the seat, providing solid closure with minimal wear; easy to turn while delivering positive shut-off; adjustable packing nut simplifies valve maintenance; back seating prevents blowouts for increased user safety; stem and bonnet threads are fully isolated from the process fluid to minimize potential corrosion; modular packing ensures only the stem and body are exposed to the process fluid. Stand 1303 — *Emerson Automation Solutions, Houston*
www.emerson.com

This control valve is now available in PN 63 and ANSI Class 600

The Ecotrol 8C control valve features a unique cage retainer/clamping seat system that enables simple maintenance without special tools, and a wide range of process-tailored valve internals, including standard parabolic plugs (either metal seated or with the patented Arca soft seal system), multistage low-noise perforated and even double-guided valve plugs. The gland packing system is certified according to TA Luft and ISO15848 Class B for a temperature range from –46 up to 200°C. Recently the Ecotrol 8C product range has been extended to valves with PN 63 as well as ANSI Class 600 with flanges or butt-welded ends. Especially for the U.S. market, a version fully designed to ASTM and ASME standards has been developed. Stand 1433 — *ARCA Flow Controls, Houston*
www.arca-valves.com ■

Gerald Ondrey



Solids Processing

special advertising section

CHEMICAL ENGINEERING

Access Intelligence

Inside:

High-end steel belts from Berndorf Band Group

Worldwide solutions for the chemical industry

Widely represented on the international stage, Berndorf Band Group provides innovative solutions for the chemical industry and unique service as a leading manufacturer of steel belts and belt systems. Thanks to its expertise and a wealth of experience built up over more than 90 years, numerous well-known manufacturing companies choose Berndorf's high-quality belts and innovative belt systems for their production facilities. Berndorf Band Group supports manufacturers at every step of the value chain. Its highly experienced experts work closely with customers to build up the optimal parameters for individual production processes. Based on this information, customized steel belts and belt systems are developed. Throughout this process, the steel belt specialists contribute their expert insights and technical know-how. With convincing quality, they have already gained numerous customers all over the world.

Quality, forward design and latest technology

Berndorf Band Group only uses premium quality steel belts. Material selection in respect of tensile strength, hardness, abrasion resistance, corrosion resistance and thermal expansion is based on careful examination of individual specifications. These premium-quality belts retain their flatness and shape even at fluctuating operating temperatures and a high number of load cycles. The production of top-quality on steel belts is possible thanks to the Group's continuous investment in research and development and close cooperation with manufacturers. The service provider develops ideas and innovations for their clients. In collaboration with various research institutes and universities, they are constantly in search of the latest trends and inform themselves worldwide about potential new markets in which steel belts and belt systems can be used optimally. Therefore, in addition to the classic steel belts and belt systems, they also offer corresponding worldwide service and repair. The company has a huge network and offers customers specially developed service equipment for the repair of steel belts.

More information about the portfolio of Berndorf Band Group: **www.berndorfband-group.com**

BEUMER Group provides palletising solutions for various packaged products, packing patterns and pallet sizes

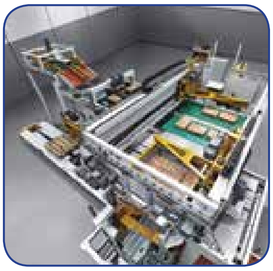
Attractive design, reliable operation

BEUMER Group, a single-source provider for filling, palletising and packaging technologies, develops complete packaging lines with perfectly compatible components. The right palletising technology is key to achieving optimally packaged load units and for the secure transportation of bags, buckets, packages or canisters. As a system supplier, BEUMER Group customises these systems, both the BEUMER paletpac and the BEUMER robotpac, to match the individual customer's needs and takes product characteristics, packing patterns and pallet sizes into consideration.

"We design the individual machine and components to perfectly fit customers' specific needs and to ensure maximum throughput on the packaging lines," describes Gregor Baumeister, Director of the Packaging and Palletising Division at BEUMER Group. This of course also applies to the palletisers: they pick up the items and stack them in the desired pattern on the respective pallets, before they are wrapped with a stretch hood. The machines have to meet high demands. "The merchandise must be stable and stacked neatly on the pallet," says Baumeister. "This ensures optimally packaged load units for secure transport on trucks for example."

Secure and neat stacks of bulk material

Products of the industries food, (petro)chemical, building materials and other consumer goods are stored in special bags, barrels, canisters, cartons or buckets. BEUMER Group offers different solutions, depending on the packaged items. The BEUMER paletpac is suited best for bulk material. This construction series stacks the bags in a stable and precise way on the pallets. The bags are made out of paper, polyethylene or polypropylene and are available in two different designs: flat valve and valve bottom bags.



The BEUMER paletpac creates precise, stable, space-saving bag stacks

Always the right gripper at hand

BEUMER Group's portfolio includes the BEUMER robotpac for palletising different bagged items or unit loads such as barrels, cartons, boxes, canisters, trays: a space-saving, fully automatic articulated robot that solves complex palletising and de-palletising challenges reliably and efficiently. The user receives gripping systems suitable for all types of packaged goods, which can be easily exchanged. "Together with our customers we have developed an extensive know-how when it comes to control technology and the development of grippers," says Baumeister. "We offer different grippers for different tasks." **www.beumergroup.com**

Handle virtually any bulk solid material

Flexicon stand-alone equipment and automated plant-wide systems convey, discharge, condition, fill, dump and weigh batch bulk materials dust-free

Flexicon engineers and manufactures a broad range of equipment that handles virtually any bulk material, from large pellets to sub-micron powders, including free-flowing and non-free-flowing products that pack, cake, plug, smear, fluidize, or separate.

Individual bulk handling equipment includes: flexible screw conveyors, tubular cable conveyors, pneumatic conveying systems, bulk bag dischargers, bulk bag conditioners, bulk bag fillers, bag dump stations, drum/box/container dumpers, and weigh batching/blending systems. Each of these product groups encompasses a broad range of models that can be custom engineered for specialized applications, and integrated with new or existing upstream and downstream processes and storage vessels.

All equipment is available to food, dairy, pharmaceutical and industrial standards.

For large-scale bulk handling projects, Flexicon's separate Project Engineering Division provides dedicated Project Managers and engineering teams on four continents to handle projects from concept to completion. Working with each customer's preferred engineering firm or directly with their in-house team, Flexicon adheres strictly to the customer's unique standards, documentation requirements and timelines through a single point of contact, eliminating the risk of coordinating multiple suppliers.

Flexicon's worldwide testing facilities simulate full-size customer equipment and systems, verify performance prior to fabrication, demonstrate newly constructed equipment for visiting customers, and study the performance of new designs.

Flexicon offers stand-alone bulk handling equipment as well as plant-wide systems integrated with new or existing processes

In 2015 the company doubled the size of its manufacturing facility and world headquarters in Bethlehem, PA, and also operates manufacturing facilities in Kent, United Kingdom; QLD, Australia; and Port Elizabeth, South Africa. **www.flexicon.com**

Ultra-high speed powder dispersion made simple

Ross SLIM Technology employs high shear for rapid and complete mixing of powders into liquids, avoiding agglomerates and dust formation

The **Ross** Solids/Liquid Injection Manifold (SLIM) is a technology for dispersing challenging powders like fumed silica, gums, thickeners and pigments using a specially modified high shear rotor/stator generator.

In both batch and inline designs, the SLIM is easy to retrofit into almost any process. In an inline set-up, the SLIM mixer pumps liquid from the recirculation tank while simultaneously drawing powders from a hopper. As the liquid stream enters the rotor/stator assembly, it immediately encounters the powder injection at the high shear zone. The mixture is then expelled through the stator at high velocity and recirculated back into the tank. In just a few short turnovers, solids are completely dissolved or reduced to the desired particle size.

This method for high-speed powder injection is ideal for dispersing small concentrations of hard-to-wet solids like CMC or xanthan gum (>5%). It is equally effective for solid loadings as high as 70%, as in the case of titanium dioxide or magnesium hydroxide slurries. By introducing solids sub-surface where they are instantly subjected to vigorous agitation, issues like floating powders, excessive dusting and formation of stubborn agglomerates ("fish eyes") are eliminated. Because the SLIM generates its own vacuum for powder induction and does not rely on external eductors or pumps, it is free of clogging and simple to operate.

Ross Inline SLIM powder induction mixer with built-in control panel mounted on a portable cart with work bench

Several models are available including automated skid packages where the SLIM mixer is piped to a jacketed tank and supplied with flowmeters, load cells, solenoid valves, level sensors and thermocouples all integrated into a PLC Recipe Control Panel. Each ingredient addition and process step can be pre-programmed so that mixer speed, mixing time, temperature, composition and batch weight are accurately replicated in every run.

Established in 1842, Ross is one of the world's oldest and largest manufacturers of process equipment, specializing in mixing, blending, drying and dispersion. **www.highshearmixers.com**

Ultra-High Efficiency Gas Absorption and Particulate Collection in a Space Saving Design

Now Achievable with Proprietary Bionomic Scrubber Technology

Overview

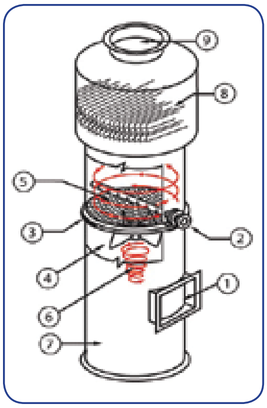
The patented RotaBed™ Fluidized Bed Scrubber represents a major breakthrough in ultra-high efficiency gas absorption and particulate collection in a space saving non-fouling design. RotaBed is the ideal technology for applications involving particulate laden gas streams or when handling high solids content or scale forming scrubbing liquids.

The key to the scrubber's superior performance is a unique swirl induced Coriolis grid that achieves much greater fluidized bed stability, resulting in more efficient gas mixing and transfer efficiency than less advanced designs. This unique approach to gas-liquid fluidization is accomplished without the need for marbles or plastic spheres that are prone to fouling or replacement due to wear. RotaBed's "packless", highly plug resistant grid cross section is up to 99% open in the fluid contact scrubbing zone and allows the scrubber to deliver exceptionally high gas throughput capacity - over three times greater than comparable size packed towers or tray scrubbers for higher scrubbing efficiency in a smaller diameter vessel.

Designed to handle gas capacities from 500 thru 25,000 cfm, RotaBed is available in mild steel, 304, 316, and AL6XN Stainless Steels, High Nickel Alloys, Titanium FRP, FRP-Dual Laminate, and Polypropylene. Pressure drop range is 1..75" thru 15" w.c. with particulate removal efficiencies of 3 microns and above from 97 to over 99.9%, and water soluble gases up to 99.99%

How It Works

During operation, gas with contaminants enters the RotaBed gas inlet(1) and flows upward. Scrubbing liquid is introduced through fully open non-clog pipe distributors(2) onto the surface of the patented RotaBed Coriolis induced fluidizing grid(3). Single or multiple grid stages are incorporated depending on the number of transfer units required to meet the needed pollutant removal efficiency. The high velocity gas travels in an angular upward path and fluidizes the liquid on the large open area grid surface. Unlike low efficiency static plug flow fluidized beds, the RotaBed shaped grid design utilizes swirl inducing vanes(4) to dramatically increase mass transfer and particulate collection via creation of a rotating Coriolis motion fluidized bed(5). Scrubbing liquid with captured pollutants then vortex drains(6) into the slump(7). The RotaBed cleaned gas passes through a two stage droplet removal stage(8) and exits through the gas outlet(9).



How RotaBed™ Works

www.bionomicind.com

A small footprint but a big step

EKATO´s lab dryers are flexible and versatile

EKATO SYSTEMS is promoting a range "desktop type" laboratory-scale dryers. With working volumes of 3-6l, the VPT 3 dryers cater to a growing demand for carrying out drying tests in vertical apparatus, and also allow small batches of product to be manufactured. Scale-up is easy because the design matches EKATO´s full-scale dryers. The base model in this plug-and-play system is a drying vessel with a water jacket for heating or cooling. The variable-speed motor accepts both the EKATO PARAVISC impeller for free-flowing solids and the EKATO ISOPAS impeller for pasty products. Working pressures range from - 1 to +2 bar(g). Vacuum is provided by a membrane vacuum pump with condensate vessel. Working temperature is up to 131°C. Contact parts are made from stainless steel, with other materials available on request. Control is via touch screen, with an electric motor used to lift the vessel lid. A data logger and an interface for remote data transfer are available on request. Just like EKATO´s production-scale dryers, the VPT 3 dryers can handle thick pastelike products just as easily as lowviscosity suspensions. For shear-sensitive active ingredients that required gently drying, the EKATO PARAVISC impeller combines uniform product circulation with good heat transfer. Varying the shaft speed allows experiments to find the shortest operating point that reliably achieves the shortest drying times or the best product properties. A rental unit is available.

www.ekato.com

EKATO SOLIDMIX VPT 3 laboratory dryers handle both free-flowing and pasty materials, and are ideal for process development

IPCO

Continuous film casting system and membrane manufacturing process

IPCO developed an innovative Venturi drying system for film casting applications, which enables manufacturers to achieve a stable, high quality product in an extremely efficient manner.

Designed in partnership with institutes specializing in coating and film casting technologies, and incorporating a slot die, the system combines high precision film casting with extremely efficient drying.

This system improves the casting process, enabling the production of film products to exceptionally narrow tolerances without any risk of skin formation or costly faults and imperfections in the final material.

Typical applications include the casting of filter membranes (cellulose acetate or nitrate), ceramic tapes, edible films (water soluble polymers) and optical films (TAC).

For the manufacturing of membranes where the porous structure is formed by a phase separation process our units provide a very uniform temperature distribution for the belt heating as well as for the process air. This results in high performance products with narrow tolerances.

While the IPCO film casting system offers a number of unique market benefits, the compact Venturi dryer can also be used in conjunction with other drying technologies including traditional impingement dryers.

The key benefits of the IPCO Venturi dryer are achieved through the use of a permeable metal foam above the drying film. A flow of tempered air is applied to the upper side of this foam-like metallic material, creating a low negative pressure on the lower side.

As a result, a constant and even suction flow is formed, delivering a homogeneous drying effect. This minimizes thermally-induced shrinkage and reduces the risk of structural defects in the surface.

IPCO has installed a full casting system with drying section at its Productivity Centre in Fellbach near Stuttgart. This is available for process assessment and product testing.

www.ipco.com

Harmonizing your Production Processes

In the manufacture of pharmaceuticals, safety and quality are the prime consideration. Here the crucial factor is the process equipment that handles the numerous interfaces between the unit operations. For over 50 years, Müller Processing has repeatedly introduced new concepts and expanded upon existing ones to optimize the various product transfer points in our customers' production lines. Where is the secret in this? Quite often not in some outstanding product innovation, but in our ongoing development work and the painstaking evaluation of the well-known and frequently occurring problems at customers' interfaces. From these findings and the expertise of individual customers, we create new combinations and variations of our modular assemblies—systems comprising vessels, handling devices and butterfly valves—which are controlled manually or fully automatically and integrated into the process operation.

Whether solutions are presented in a compact summary or in great detail, you rapidly gain an overview of what we - as a single-source provider of process equipment - can offer you.

Standards Give Rise to New Ideas

Every innovative technology begins with an idea. Especially with complex projects, competent engineering creates a good conceptual environment right from the start, ensuring that the work of installing the system and integrating it into the production line proceeds smoothly and that the start-up goes quickly.

Our solutions deliver sustainable long-term benefits for your business. Learn more about us.

www.muellerprocessing.com

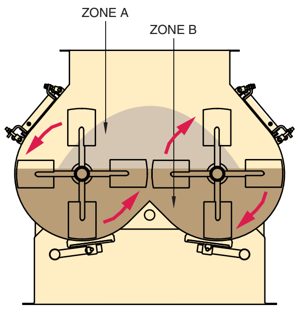
Fast, homogenous mixing

The Bella XN fluidized zone mixer from Dynamic Air is a twin-shaft design that uses a "weightless" central fluidized area to provide thorough yet gentle mixing of dry products

The twin-shaft Bella mixer

The Bella fluidized-zone twin-shaft paddle mixer by **Dynamic Air** achieves fast, high-capacity, low-shear, precision mixing of either dry bulk solids or liquids with solids. Regardless of particle size, shape or density, materials are mixed with a fast, efficient, and gentle action, with typical mixing times of 15–30 s. A weightless zone created by low-speed counter-rotating paddles generates low friction without shear. This makes it ideal for abrasive products and fragile products that cannot tolerate rough handling. Even flakes or spray-dried bodies remain intact.

The Bella mixer consists of twin drums which have two counter-rotating agitators with specifically angled paddles. The paddles sweep the entire bottom of both mixer drums and yet allow the mixer to be started under full load (Figure 1). The material in the mixer moves in a horizontal counter-clockwise direction at the perimeter



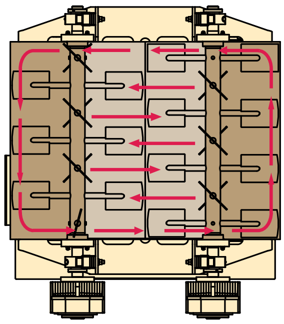


Figure 1 (right, top): In Zone A, fluidization promotes thorough mixing. Figure 2 (right): Material interchange between the two drums

while simultaneously moving both left and right in the center (Figure 2). The material in Zone B (Figure 1) is in its normal gravimetric state as it is being moved and dispersed. In Zone A, a weightless zone is created which effectively lifts the ingredients to an almost weightless state, allowing them to move freely and randomly, regardless of particle size and density. Thus the two zones' interaction becomes highly efficient as every particle moves rapidly to create a highly homogeneous mix, the key to the Bella mixer mixing technology for fast, precise mixing.

The Bella mixer is available in stainless steel and mild steel construction.

www.dynamicair.com/products/mixers.html

Automated proof testing

With Heartbeat Technology and Himax safety controller

Generally carried out on an annual basis, proof testing of SIL safety systems places significant demands on companies in the chemical, and oil and gas industries in terms of the associated cost and complexity.

Flowmeters must be removed and recalibrated in some cases causing plant shutdown. With this specific application in mind, the HIMax safety controller from HIMA, combined with Endress+Hauser's Heartbeat Technology, now enables automatic proof testing of flowmeters, for example. The advantages include:

- Error-free automatic testing
- Test conducted at the optimum time without the need for device removal or plant shutdown
- Guaranteed safety of the process prevents systematic errors
- Unambiguous test results and extensive monitoring parameters enable predictive maintenance

In addition to a comprehensive device verification with a high diagnostic coverage of up to 98 %, extensive trend monitoring parameters are read out enabling predictive maintenance for the first time. The Himax safety controller manages the test and initiates it at the optimum time in the plant's process. As part of the test procedure, SIL mode is first unlocked in the measuring device via the HART interface and in compliance with NE 154. A thorough device verification is then carried out.

Heartbeat Technology

In addition to a clear pass/fail test result, useful monitoring parameters such as, e.g., the HBSI (Heartbeat Sensor Integrity) value of a Promass Coriolis mass flowmeter can be read out. This means that, now for the first time, clear conclusions can be drawn in relation to the condition of a device and its wear reserve. Finally, the device is SIL-locked again.

The data are not only forwarded, e.g. for maintenance purposes, but the detailed test results are also stored in the device with up to 8 data records. They can be transferred to test reports via Field Care during audits in such a way that they are tamper-proof.

www.endress.com

Jenike & Johanson Engineering Services

Jenike & Johanson, Inc. is the world's leading technology company for bulk material handling, processing, and storage. They deliver engineered solutions to achieve reliable powder and bulk solids flow based on proven theories and decades of project experience. With their skilled, highly technical team of experts and industry-leading innovations, they have successfully delivered bulk material engineering solutions for more than 55 years.

Bulk materials and their flow properties are at the core of all Jenike & Johanson's work. Every project (7,500+ to date) is truly unique. Clients are offered maximum flexibility in selecting services required to meet their bulk material handling needs. Jenike & Johanson does not follow the "one size fits all" concept – which can be a dangerous pitfall in engineering. Decisions made during the feasibility and engineering stages of a project are critically important for its success. If bulk solids systems are not engineered from the outset to handle the unique characteristics of the materials, process start-up time can be significantly delayed and design capacity may never be reached.

The engineers at Jenike & Johanson are renowned experts in the field of bulk material engineering. They are frequent keynote speakers at major industry events, routinely deliver informative webinars and customized courses, and publish thoughtful technical articles in top industry journals and publications – all this in order to provide clients with the latest insight on cutting-edge methodologies which make the powder and bulk solids handling aspect of the business run seamlessly.

The chemicals industry provides the building blocks for companies manufacturing paints, pigments, coatings, adhesives, resins, consumer products, and foods. 75% of all chemicals are handled in bulk solid form during manufacturing. When feeding powders to reactors or conveying wet cake from a centrifuge to a dryer, poor material flow can result in throughput limitations, non-uniform product, or dust emissions/spillage.

www.jenike.com

Rota-Cone® Blender

The **Paul O. Abbe** Rota-Cone® blender is the ideal choice for thorough and gentle blending of powders or crystalline products. Because this tumble blender has no shaft seals or agitator, cleaning is simplified and cross-contamination minimized. All internal surfaces the Rota-Cone® can be inspected from the single loading hatch.

Liquids can be added through the optional spray line and a pin agitator can be added to facilitate liquid dispersion, granulation or de-agglomeration. Loading can accomplish with our automated drum loading and discharging system. Controls including variable frequency drive and PLC can be supplied in NEMA-4X or NEMA-7&9 explosion-proof design. Available sizes range from 0.1 to 500 cubic feet working capacity.

www.pauloabbe.com

Stainless Steel Butterfly Valve

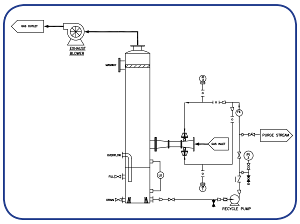
The **Posi-flate** butterfly valve with a highly polished 316 stainless steel housing and disc is suitable for many applications, such as food, chemical and pharmaceutical. The inflatable seat design of the Posi-flate butterfly valve provides a better seal by utilizing air pressure to expand the seat against the disc, providing more sealing area and an even pressure distribution against the disc every time. The seat automatically compensates for wear when it inflates against the disc, extending valve life considerably. Because the Posi-flate disc only makes casual contact with the seat during opening and closing, torque requirements are substantially lower. This ease of movement also allows the disc to come to a perfect 90-degree position every time. Additionally, the smooth profile of the disc helps material flow easier and reduces build-up. The Posi-flate stainless steel butterfly valve is available in sizes of 2" (50mm) to 20" (500mm).

Stainless Steel Posi-flate Butterfly Valveensure that products are free-flowing

www.posiflate.com

CR Clean Air High Energy Venturis for Particulate Control

CR Clean Air offers customized solutions for the reduction of PM10, PM2.5 and submicron particulate.



If you're dealing with solids processing, you probably have dust. It's not fun. It clogs equipment. Finer particles can cause health issues and PM 10 and PM 2.5 are regulated by both the EPA and OSHA. What is a plant to do? Any well designed HVAC system will have enough air changes to keep the dust to a minimum, but that air has to go somewhere. Filters not only add pressure drop, but they need to be cleaned or replaced periodically. There has to be a better way.

Thankfully, a wet scrubber may be the answer. **CR Clean Air** can custom engineer a high energy venturi to help control your overall particulate emission. Consisting of a venturi followed by a cyclonic separator tank, particulate laden exhaust gases are pulled through the venturi by use of a downstream blower. Water is sprayed into the upper cone of the venturi perpendicular to the gas flow. The venturi imparts a significant pressure drop (thus the term high energy) on the vapor, causing the particulates to be forced into the liquid phase. The resulting two phase mixture is then separated in the cyclonic tank, with the gas entering tangentially. The tank has a mist eliminator at the top to prevent liquid droplets from being entrained in the effluent gas leaving the scrubber.

With sizes ranging from a few CFM to units capable of handling over 10,000 CFM, CR Clean Air can customize a design to meet almost any capacity. Removal rates for particles larger than PM 10 exceed 99.9%, and can also remove 99% or more of PM 2.5 and smaller, down to 1 micron. These high energy scrubbers will also remove 90 % or more of all but the smallest submicron particulates. With anything 0.25 micron or larger being readily removed under most situations.

As an advantage, liquid can be recirculated to the venturi with minimal blowdown in order to minimize overall water usage. For varying vapor loads, our venturis are available with an optional variable throat, which can impart a constant pressure drop irrespective of the gas flow.

So, the next time you have solids in your exhaust gas stream, why not consider installing a CR Clean Air high energy venturi? CR Clean Air… when it hast to work the first time, and every time – you can trust a CR Clean Air scrubber to get the job done!

wwwcrcleanair.com

Flameless Venting

CV **Technology** is proud to announce that the Interceptor-QR is the first flameless venting system to have completed a FM Approval to the new Approval Standard 7730. The 7730 standard is the most recent and most rigorous testing methodology to have been developed. Using the methodology stresses the devices under more realistic conditions than had been developed by previous standards. CV Technology continues to be a pioneer in the combustible dust protection industry with the most complete certification for flameless venting technology in the world.

The dust and flame retention capability of the Interceptor-QR make it ideal for indoor explosion venting applications. With a simple installation, easy refurbishment, and process friendliness, the Interceptor-QR is a superior explosion mitigation technology. Interceptor-QR flameless vents can be used on a variety of process equipment. These vents are designed to be used on equipment located indoors since they eliminate the release of a flame ball. Flameless vents are ideal for pneumatic conveying equipment, dust collectors, bins, cyclones, bucket elevator, mills, silos and dryers.

For more information about CV Technology or flameless vents, please call 561-694-9588 or visit

www.cvtechnology.com

2017 2018 2019

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Mar. '19 Prelim.	Feb. '19 Final	Mar. '18 Final
CE Index	616.0	617.1	588.0
Equipment	752.8	754.7	713.3
Heat exchangers & tanks	668.3	674.7	626.0
Process machinery	728.9	728.6	703.4
Pipe, valves & fittings	977.7	971.7	930.4
Process instruments	421.3	418.8	417.9
Pumps & compressors	1066.0	1063.8	1017.7
Electrical equipment	557.5	554.4	532.8
Structural supports & misc.	827.7	838.4	763.3
Construction labor	334.3	333.7	331.3
Buildings	599.7	599.7	582.1
Engineering & supervision	316.9	316.8	310.0

Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

Annual Index:

2011 = 585.7

2012 = 584.6

2013 = 567.3

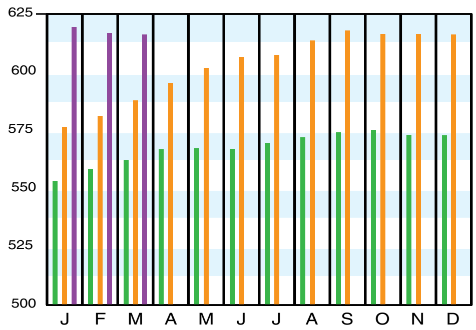
2014 = 576.1

2015 = 556.8

2016 = 541.7

2017 = 567.5

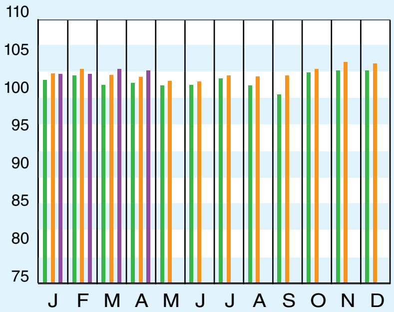
2018 = 603.1



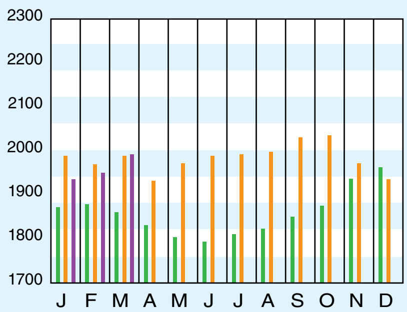
CURRENT BUSINESS INDICATORS

	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2012 = 100)	Apr. '19	=	103.2	Mar. '19	=	103.1	Feb. '19	=	103.3	Apr. '18	=	103.0
CPI value of output, $ billions	Mar. '19	=	1,992.8	Feb. '19	=	1,955.5	Jan. '19	=	1,937.7	Mar. '18	=	1,934.7
CPI operating rate, %	Apr. '19	=	77.3	Mar. '19	=	77.3	Feb. '19	=	77.5	Apr. '18	=	77.6
Producer prices, industrial chemicals (1982 = 100)	Apr. '19	=	255.9	Mar. '19	=	257.9	Feb. '19	=	255.1	Apr. '18	=	269.9
Industrial Production in Manufacturing (2012 =100)*	Apr. '19	=	104.7	Mar. '19	=	105.2	Feb. '19	=	105.2	Apr. '18	=	104.9
Hourly earnings index, chemical & allied products (1992 = 100)	Apr. '19	=	185.4	Mar. '19	=	184.0	Feb. '19	=	185.3	Apr. '18	=	187.3
Productivity index, chemicals & allied products (1992 = 100)	Apr. '19	=	96.6	Mar. '19	=	95.7	Feb. '19	=	96.0	Apr. '18	=	97.7

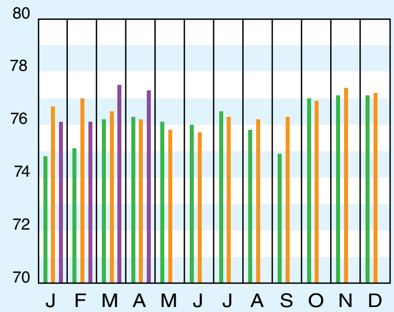
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top; the most recent available) for March 2019 decreased from the previous month's value for the second consecutive month, although the final value for February was adjusted slightly upward. The decline in March seems to be a result of a decrease in the Equipment subindex — a dip there offset very small increases in the Engineering & Supervision and Construction Labor subindices. The Buildings subindex remained unchanged. The overall CEPCI preliminary value for March 2019 stands at 4.8% higher than the corresponding value from a year ago. Meanwhile, the CBI numbers for March 2019 (middle) show a very small increase in the CPI Output index.